ESSAYS ON THE IMPACT OF SOCIAL AND PSYCHOLOGICAL FACTORS ON STRATEGIC FIRM DECISIONS

A Dissertation

by

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ABSTRACT

Traditional economic analysis assumes that consumers are fully rational and consumer preferences are independent of consumers' social context. Research has shown ample evidence that consumer preferences may vary by the social context of consumption, and social and psychological factors influence consumers' decision making. This dissertation examines the effects of social and psychological factors on consumers' decision making and how firms make strategic product and pricing decisions to respond to these effects. In the first chapter of the dissertation, I examine how firms selling repeated-purchased products price discriminate consumers based on consumers' purchase history data, given that consumers are concerned about price fairness. In the second chapter, I examine how firms selling durable goods introduce product upgrades, given that consumers' utility from consuming a product depends on the relative standing of the product in the marketplace. In the third chapter, I examine how firms selling status products make the design differentiation decision for their product lines, given that product design reveals consumers' social group and consumers have status considerations. In the above research, I provide qualitatively new insights on the impact of psychological and social factors on firms' strategic decisions and offer important implications for managers and public policy makers.

To my parents, To my husband, To my daughter. I wouldn't be where I am today without their unconditional love and support. To the Lord who leads me through the Ph.D. program. HE is my source of strength, wisdom, joy, and peace.

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1 INTRODUCTION

Firms tracking consumer purchase information often use behavior-based pricing (BBP), i.e., price discriminate between consumers based on preferences revealed from purchase histories. However, behavioral research has shown that such pricing practices can lead to perceptions of unfairness when consumers are charged a higher price than other consumers for the same product. The first essay of the dissertation studies the impact of consumers' fairness concerns on firms' behavior-based pricing strategy, profits, consumer surplus, and social welfare. Prior research shows that BBP often yields lower profits than profits without customer recognition or behavior-based price discrimination. In contrast, we find that firms' profits from conducting BBP increase with consumers' fairness concerns. When fairness concerns are sufficiently strong, practicing BBP is more profitable than without customer recognition. However, consumers' fairness concerns decrease consumer surplus. In addition, when consumers' fairness concerns are sufficiently strong, they reduce inefficient switching and improve social welfare.

Behavioral literature has established that consumers exhibit context-dependent preferences, i.e., a consumer's preference for a product is influenced by products that other consumers use in the choice context. Compared to other consumers, using a superior product induces a psychological gain and using a superseded product induces a psychological loss. Context-dependent preferences are of particular relevance for firms introducing successive generations of product upgrades because the presence of consumers using the upgraded product alters the choice context and shifts preferences. The second essay of the dissertation investigates how firm's upgrade introduction strategy changes to take into account consumers' context-dependent preferences. We find that context-dependent preferences increase firm's incentive to introduce low-cost upgrades while decreasing incentive to introduce high-cost upgrades. The reason is that low-cost upgrades with minor quality improvement target low-valuation consumers who did not buy the base product and context-dependent preferences motivate these consumers to buy the upgrade. In contrast, high-cost upgrades with major quality improvement also attract existing consumers of the firm's base product to buy upgrades. However, context-dependent preferences discourage existing consumers from purchasing upgrades. We also find that sometimes context-dependent preferences can decrease profits from introducing upgrades but yet lead to higher overall profits for a firm. This is because firm may suffer from a commitment problem: ex post it prefers to introduce upgrades, but strategic consumers anticipate this and wait for the upgrade, which makes it ex ante more profitable for firm not to introduce upgrades. Context-dependent preferences can resolve this commitment problem by rendering future introduction of upgrades unprofitable. As a result, the firm obtains a higher profit from selling a base product over time than the profit it receives from selling sequentially upgraded products. We also show that the firm may not want to offer a discounted price for existing consumers to buy upgrades, even though this upgrade pricing is preferred without context-dependent preferences. We also discuss several extensions of our models such as endogenous quality improvement, alternative formulations of reference points, settings with more than two time periods, and firm introduces two products simultaneously.

Should brands selling status goods design high-end and low-end products to look the same or different? In the third essay of the dissertation, we study how brands make this exterior design differentiation decision. We first analyze the impact of a brand's exterior design differentiation decision on consumers' preferences for the brand's products using ten years of data of a status good (cars). We find that consumers prefer high-end products of a brand to look more differentiated but prefer low-end products of the brand to look less differentiated, which seems to present brands a product design dilemma, i.e., neither design unification nor diversification within a brand can enhance the appeal of the brand's high-end and low-end products at the same time. Based on this finding, we set up a game-theoretic model to analyze brands' equilibrium design strategies. Interestingly, we find that the opposing preferences for design differentiation can lead symmetric brands to choose asymmetric design strategies, i.e., one brand unifies design while another brand diversifies design, which can be a win-win outcome. We also give conditions where both brands unify design or both brands diversify design while the latter can be a prisoner's dilemma. In addition, we show that the exterior design decision has important implications on how brands should set prices and functionalities of products.

2 BEHAVIOR-BASED PRICING: AN ANALYSIS OF THE IMPACT OF PEER-INDUCED FAIRNESS*

2.1 Introduction

Firms often use internet cookies, IP addresses, loyalty cards, user logins to track and store information about individual customer's purchase history. This enables them to charge a customized price based on purchase history. Practice of such behavior-based pricing (BBP) is common in a wide range of industries (Fudenberg and Tirole 2000; Fudenberg and Villas-Boas 2006). For example, cash registers print out customized coupons based on the content of customers' grocery cart (Woolley 1998). Airlines want passengers to identify themselves before they see fares so that airlines can charge passengers based on their booking history (Seaney 2013, WWID 2013). Amazon, the largest e-commerce vendor sold the same DVD movies for different prices to different customers based on purchase history (Streitfeld 2000). Behavioral-based pricing is also commonly used by competing firms. For example, phone, internet, and insurance providers offer discounts for new customers to switch from a competitor. Credit card companies offer zero interest rate for new

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*Reprinted with permission from "Behavior-Based Pricing: An Analysis of the Impact of Peer-Induced Fairness" by Krista Jiaoyang Li and Sanjay Jain, 2016. Management Science, 62, 9, 2705-2721, Copyright [2016] the Institute for Operations Research and the Management Sciences, 5521 Research Park Drive, Suite 200, Catonsville, Maryland 21228 USA.

customers to transfer balance from a competing company (Chen 2005). However, past customers who continue to stay with the same company are not qualified to receive these favorable offers. Prices of the same product are effectively different between new and past customers who differ in purchase history.

The prevalence of behavior-based price discrimination has raised significant concerns about price fairness. Consumers dislike buying a product and finding out that their friends or neighbors or someone on the Internet are getting exactly the same product for a lower price. According to a survey of American shoppers online and offline, 76% of American adults said they would be bothered to learn that other people pay less for the same products (Turow et al. 2005). Consumers perceive price discrimination to be unfair, especially if they pay higher prices than others (Huppertz et al. 1978, Haws and Bearden 2006, Jin et al. 2014), and therefore firm's behavior-based price discrimination can backfire. For example, Amazon angered customers, who discussed DVDs at the website DVDTalk.com and noticed that they were charged as much as 40% more than other consumers (Streitfeld 2000, Taylor 2004). Consumers' resentment about firms' BBP practice has also caught the attention of public policy makers. There has been a debate among policy makers about forcing firms to disclose BBP practice to customers. For instance, in 2012, an E-STOP (Ensuring Shopper Transparency in Online Pricing) Act was suggested to promulgate rules requiring Internet merchants to disclose to consumers whether their personal information was accessed for price discrimination. A violation of this Act would be deemed unfair or deceptive under the Federal Trade Commission Act (112th Congress

2012).

As the public becomes increasingly aware of firms' BBP practice and concerned about fairness of price discrimination, firms cannot be blind to such concerns. Customers' fairness concerns have important implications for firms, as consumers may not buy products sold at "unfair" prices, even though the material value of products exceeds the "unfair" prices (Rabin 1993, Campbell 1999, Anderson and Simester 2010). Therefore, firms serving fairness-minded consumers need to carefully think about the following questions: How should firms adjust BBP strategies to respond to consumers' fairness concerns? How would consumers' fairness concerns affect firms' profits? When consumers exhibit fairness concerns, is BBP a profitable business practice? For public policy makers who aim to protect consumers and improve welfare, it is important to understand the implications of consumers' fairness concerns on consumer surplus and social welfare. Despite the importance of these questions, existing research on behavior-based pricing has not incorporated consumers' fairness concerns into a formal analysis. In this paper, we attempt to fill this gap.

One common finding in the BBP literature is that when firms recognize customers and condition prices on purchase history, profits are lower than when firms can credibly forsake customer recognition or behavior-based price discrimination (Fudenberg and Villas-Boas 2006). This is because when purchase history information is available, each firm is better off when it unilaterally uses this information for price discrimination: it offers a higher price to its past customers and a lower price to poach the competitor's customers.

However when all firms use purchase history information and poach each other's customers, behavior-based pricing works to the detriment of all firms. This is because firms cannot extract surplus from past customers as much as when poaching is banned. Price competition becomes more intense and profits are lower than without customer recognition. Therefore, firms would be better off if they could commit to abandoning behavior-based price discrimination. There is some research which has attempted to show conditions under which BBP can be profitable. This has been primarily achieved by augmenting the strategy space of firms. For example, Acquisti and Varian (2005) allow sellers to provide enhanced services to previous customers and show that sometimes BBP can be profitable. Pazgal and Soberman (2008) show that the firm that has more capability to provide benefits for its past customers can benefit from behavior-based discrimination. Shin and Sudhir (2010) allow firms to charge different prices to high-value customers and low-value customers. They again find that BBP can sometimes be more profitable. In this paper, we incorporate consumers' fairness concerns in a standard dynamic pricing model and investigate whether fairness concerns can make BBP a business practice that yields higher profits than without customer recognition.

We build a two-period model with horizontally differentiated firms selling non-durable products. Consumers have heterogenous valuations and are uniformly distributed on a Hotelling line. In the first period, consumers' valuations are private information, which can be partially revealed by their purchase decision made in this period. At the beginning of the second period, firms observe individual consumer's purchase history and recognize whether a consumer purchased from itself or the competitor. Based on this information, firms can charge different prices to its past customers and the competitor's customers. We model fairness concerns by assuming that in any period if a customer is charged a higher price than the firm charges other customers, the customer who pays the higher price experiences a negative utility because of perceived unfairness of the price discrimination (Ho and Su 2009, Chen and Cui 2013). In the second period, past customers who stay with the same firm pay a higher price than competitor's customers who receive a switching discount. Hence, past customers exhibit fairness concerns. We analyze how the degree of the fairness concerns affects consumer decision and firms' competitive pricing strategy. In addition, we examine the implications of fairness concerns on firm's profits, consumer surplus, and social welfare.

We find that firms' total discounted profits from conducting BBP increase with consumers' fairness concerns. This result arises despite the fact that fairness concerns lead to lower profits in the second period. However, our results show that fairness concerns soften price competition and reduce price sensitivity of demand in the first period. As result, fairness concerns allow firms to charge higher prices and increase profits in the first period. The increase in the first period profits offsets the decrease in the second period profits, and total discounted profits over two periods increase with the degree of fairness concerns. Furthermore, when fairness concerns are strong enough, the total discounted profits with BBP exceed the total discounted profits without customer recognition. In addition, intuition suggests that past consumers who are unfairly price discriminated by a firm would be motivated to switch to the competing firm. In doing so, the consumer would receive a switching discount from the competing firm and avoid the uneasy feeling of being unfairly charged by the original firm. However, this intuition ignores the strategic impact of fairness concerns on firms' prices. In contrast to this intuition, we find that fairness concerns discourage switching, because fairness concerns lead to lower prices for past customers but higher poaching prices for switching customers. These price changes encourage consumers to stay with their original firm even though they are unfairly discriminated. We also show that as consumers become more concerned about price fairness, consumer surplus decreases. This result implies that although public policies that require firms to disclose their practice of BBP to consumers can raise consumers' awareness of price discrimination, growing concerns of price fairness can hurt consumers. Lastly, fairness concerns discourage inefficient switching, enhancing social welfare when consumers are sufficiently concerned about price fairness. These findings can guide firms to design BBP strategies in today's marketplace with fairness-minded consumers, shed light on the public policy implications of growing concerns about price fairness, and add new insights to the literature.

We extend our main model to verify the robustness of our results and examine the differences between fairness concerns and alternative behavioral mechanisms. Specifically, we consider a more general framework that allows for several alternative behavioral factors. First, we allow consumers to form price perception based on historical prices they paid. Second, we capture the potential utility gain experienced by consumers who switch and receive a deal or possible fairness concerns expressed by these advantageously discriminated consumers. Third, we allow consumers' fairness concerns to be endogenously determined by the number of consumers who receive a discount. Lastly, we extend our base model to allow for switching costs. Our results hold in these extensions and reveal the unique role played by fairness concerns.

2.1.1 Related Literature

Our work is closely related to the behavior-based pricing literature (see Fudenberg and Villas-Boas 2006 for a comprehensive review). Villas-Boas (2004) analyzes a market with an infinitely lived monopolist and overlapping generations of consumers who each lives for two periods. In his model, the firm can recognize past customers but cannot differentiate between customers who did not buy last period and customers who just entered the market. He shows that the monopolist is worse off than if it could not recognize its previous customers. Villas-Boas (1999) studies competition in a similar setup. He shows that firms lower prices to attract competitor's previous customers and prices are lower than when there is no customer recognition. Fudenberg and Tirole (2000) study competing firms' poaching behavior and show that poaching reduces total discounted profits. Even though fairness is not incorporated in their model, the authors acknowledge that "loyal customers may feel resentment if they know that others receive better terms" (p.643). Acquisti and Varian (2005) study the optimality of conditioning prices on purchase history when firms can commit to doing so or not. They show that if competitive sellers offer enhanced services to previous customers, conditioning prices on purchase history can be profitable. However, in the standard framework with constant product offerings, a seller will not find it optimal to price discriminate between high-value and low-value customers even though it is feasible to do so. Pazgal and Soberman (2008) allow differentiated firms to be able to make a credible commitment about whether to conduct BBP and offer additional benefit to past customers. They show that BBP generally leads to lower profits for firms with identical ability to add value to the second-period offer. Shin and Sudhir (2010) allow consumer preferences to change over time and consumers are heterogeneous in purchase quantity. They allow firms to charge different prices to high-value and low-value past customers. They show that if consumers are sufficiently heterogeneous in purchase quantity and preferences are sufficiently stochastic over time, BBP can be profitable for firms. Zhang (2011) examines endogenous location choice in a two-period poaching model, in which firms can offer customized products and prices to consumers based on purchase history. She shows that behavior-based personalization reduces design differentiation and intensifies price competition between firms. Our work attempts to make a contribution to this body of literature by examining the implications of consumers' fairness concerns on firms' behavior-based pricing strategy and showing that when consumers are fairness-minded, BBP can generate higher profits than without customer recognition.

This paper is closely related to the growing stream of literature that incorporates fairness concerns into firms' optimal strategies. Fehr and Schmidt (1999) propose a model of "inequity aversion" to capture the notion that consumers experience a disutility from receiving a payoff that is different from the others. Disadvantageous inequity affects consumers more strongly than advantageous inequity. Particularly, fairness concerns that arise from situations in which agents' preferences depend on payoffs of peers are categorized as *peer-induced fairness*, and those depend on payoffs of other economic agents such as firms are categorized as *distributional fairness*. Cui et al. (2007) examine optimal channel coordination when channel members have distributional fairness concerns. Guo (2015) studies firms' optimal selling strategies and welfare implications when buyers are concerned about distributional fairness and ex-ante uncertain about seller's variable cost. The author shows that seller's ex-ante profits may increase as more buyers become inequity averse. Guo and Jiang (2015) examine a firm's quality and pricing decisions when consumers have distributional fairness concerns and are uncertain about firm's costs. They find that inequity aversion may benefit an efficient firm and hurt an inefficient firm and reduce consumers' monetary payoffs. Ho and Su (2009) analyze ultimatum games played sequentially by a leader and two followers. They find that peer-induced fairness between followers is two times stronger than distributional fairness between leader and follower. Chen and Cui (2013) show that a uniform price for branded variants may arise in equilibrium because of consumers' concerns of peer-induced fairness. We study firm's behavior-based price discrimination, where consumers are mostly concerned about the discriminatory prices they pay in comparison to prices other consumers pay. Therefore, we consider the impact of peer-induced fairness on firms' BBP strategy. We also develop a model which incorporates fairness concerns in a dynamic setting.

Feinberg et al. (2002) also examine situations in which consumers care about prices that are available to other consumers. In their framework consumers are less likely to purchase from firms which offer a better deal to other consumers. Their results suggest that as more consumers become aware of prices that are offered to switchers, firms will not find it profitable to offer better deals to switchers. In contrast to their research, we develop a utility-based model with endogenous pricing in a dynamic setting. We find that endogenizing prices changes the results substantially. In particular, we show that with endogenous prices, fairness concerns can decrease switching because firms adjust second-period prices to alleviate fairness concerns which encourage consumers to stay with their original firm. Furthermore, we find that fairness concerns can make BBP with lower prices to switchers more profitable because past customers' fairness concerns allow firms to raise first-period prices when purchase history data are produced.

Another stream of related research is the literature on switching costs (see Klemperer 1995, and Farrell and Klemperer 2007 for extended surveys). Klemperer (1987a) studies a two-period duopoly model where consumers are partially locked-in by switching costs in the second period. He shows that switching costs soften price competition and increase profits in the second period but could make first period price competition more intense. Klemperer (1987b) shows that noncooperative behavior in the presence of switching costs can lead to collusive outcomes in mature markets (i.e., the second period). However, competition in the new market (i.e., the first period) becomes more intense. The author finds that firms are worse off paying customers to switch than offering uniform pricing. Shaffer and Zhang (2010) study firms' price discrimination between own customers and their rivals' customers when consumers face endogenous switching costs. They find that sometimes it may be profitable to charge a lower price for one's own customers. Our paper differs from this stream of research by focusing on the impact of consumers' fairness concerns on firms' behavior-based pricing strategy, which in turn affects consumers' switching decision and firms' profits.

Our paper also adds to the burgeoning research in marketing that incorporates consumers' psychological behaviors into quantitative models. This stream of research enriches traditional economic models and provide new insights (e.g. Amaldoss and Jain 2005, Cui et al. 2007, Villas-Boas 2009, Kuksov and Villas-Boas 2010, Chen et al. 2010, Guo and Zhang 2012).

The rest of the paper is organized as follows. In §4.3, we introduce the model setup and present the benchmark model. In §2.3, we present the main model and analysis. In this section, we investigate how fairness concerns impact firms' BBP strategy in a duopoly. In §2.4, we extend the base model in several aspects. We conclude with managerial implications and directions for future research in §2.5.

2.2 Model

We consider a two-period model of a duopoly.* In each period, two horizontally differentiated firms sell a non-durable product to consumers. Each consumer demands at most one unit of the product in a period. Let r denote the base value of the product. We

*For completeness, in the Technical Appendix B, we analyze how fairness concerns affect a monopolist that conducts behavior-based pricing.

assume r is sufficiently high so that the market is fully covered and two firms compete for the marginal consumer. Consumers are uniformly distributed over a Hotelling line with range $[0,1]$. Firm A is located at 0 and firm B is located at 1. A consumer's location on the line is denoted by θ. Without fairness concerns, if a consumer at θ purchases a product from A at price p_a, his utility in that period is $r - t\theta - p_a$, where t represents the transportation cost. If the consumer purchases a product from B at price p_b, his utility is $r - t(1-\theta) - p_b$. To focus on the effect of fairness concerns, we assume there are no switching costs. In §4.4.4, we will incorporate switching costs into the model. Finally, the respective discount factors for firms and consumers are δ_f and δ_c.

2.2.1 No Customer Recognition

First consider the benchmark model without customer recognition or behavior-based price discrimination. Behavior-based price discrimination may not exist either because it is illegal and banned by law, or because firms do not have the ability to store or utilize purchase history information. In this case, firms cannot charge customized prices. The two-period game becomes a repetition of a static game. We summarize the equilibrium of this benchmark model in the lemma below (see the Technical Appendix A for the proof).

Lemma 1 ***(Equilibrium Without Customer Recognition)*** *Without customer recognition, in each period, two firms simultaneously charge a price of t. Each firm serves half of the market and earns a profit of $\frac{t}{2}$. Over two periods, each firm earns a total discounted profit of $\frac{(1+\delta_f)t}{2}$.*

Since firms do not price discriminate among consumers, all consumers pay the same price and do not exhibit fairness concerns.

2.3 Customer Recognition

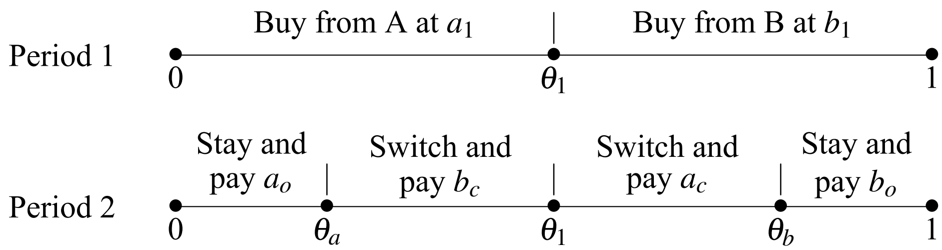
Now consider situations in which firms can recognize consumers and use purchase history collected in period 1 to price discriminate consumers in period 2. We solve for the symmetric pure-strategy equilibrium backwards. We will discuss consumer choice and firms' pricing decisions in each period separately.

2.3.1 The Second Period

In the second period, firms have information of consumers' purchase history. The purchase history indicates if a consumer purchased the product from firm A or B in period 1, which reveals the consumer's relative preference for two firms' products. From a firm's perspective, the purchase history partitions the second-period market into two segments: a segment of past consumers who purchased from the firm in period 1, and a segment of consumers who purchased from the competitor in period 1. Given this information, a firm can charge all consumers the same price. However, such uniform pricing is (weakly) dominated by a customized pricing scheme. As a result, each firm has an incentive to charge two different prices to customers in the two segments.

Now let us understand how fairness concerns affect firms' pricing strategy in the second period. Let a_o and a_c denote the prices firm A charges its own customers and the competitor's customers in the second period. Similarly, b_o and b_c denote the second pe-

Figure 2.1: Consumer Choices in Periods 1 and 2



riod prices B charges its own customers and competitor's customers. In equilibrium, high-valuation customers located near the two firms purchase repetitively from their preferred firms, whereas low-valuation customers near the center of the line switch (see Figure 2.1).

The consumer at θ_a is indifferent between buying from firm A at price a_o and switching to buy from firm B at the poaching price b_c. When consumers care about the fairness of firms' pricing strategy, having to pay a higher price than others for the same product is perceived as unfair. With such fairness concerns, the consumer at θ_a is characterized as follows.

$$r - t\theta_a - a_o - \lambda \cdot \max(a_o - a_c, 0) = r - t(1-\theta_a) - b_c - \lambda \cdot \max(b_c - b_o, 0) \qquad (2.1)$$

The left hand side of (2.1) is the utility of buying from firm A at the past-customer price a_o. If this past-customer price is higher than the price a_c that switchers pay, paying the price premium of $(a_o - a_c)$ induces negative feelings of unfairness and the magnitude of disutility is $\lambda \cdot \max(a_o - a_c, 0)$.[†] The parameter λ represents the degree of consumers'

[†]An alternate approach would be to assume that consumers care about the prices that they pay in period 2 relative to what they paid in period 1. If period 2 prices are higher, then consumers experience fairness based disutility. However, as we will see later in our analysis and as has been shown in the prior literature, prices under behavior-based pricing decrease over time. Therefore, under this approach the analysis reduces

fairness concerns and ranges from $[0,1]$.[‡] If $\lambda = 0$, fairness concerns do not exist and consumption utility is not affected by price differential relative to other consumers. Here we assume that all consumers share the same λ, i.e., consumers are homogeneous in their concerns about price fairness. We will relax this assumption and consider heterogeneity in consumers' fairness concerns.

The right hand side of (2.1) is the utility of switching to firm B to buy at B's poaching price b_c. If the poaching price b_c is higher than B's past-customer price b_o, consumers who switch would exhibit fairness concerns. The decrease in utility due to this fairness concern is $\lambda \cdot \max(b_c - b_o, 0)$. Consumers who pay a lower price than others may also perceive firms' price discrimination to be unfair. However, research has shown that disadvantageously discriminated consumers are more concerned about price fairness than those who are advantageously discriminated (Lowenstein et al. 1989, Fehr and Schmidt 1999). Consistent with prior research, we model the disadvantageous fairness concerns (Ho and Su 2009, Guo 2015, Guo and Jiang 2015). However, we relax this assumption in §2.4.1 and find that our results are even stronger when we allow for advantageous inequity aversion. Alternatively, one may argue that these consumers may experience a utility gain from paying less for the same product than other consumers. Although this utility gain is not driven by fairness concerns, it may arise as a result of the behavioral pricing scheme. In

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to the standard model. Alternatively, since the first period prices are higher than the second period prices, consumers may experience a gain when they use the price they paid in the first period as a reference price to evaluate the second period prices. In §2.4.2, we will extend our base model to consider this situation.

[‡]We assume that λ is bounded by 1. If λ exceeds 1, it would imply that consumers would be willing to give up more than one dollar to avoid one dollar price difference that he overpays in comparison to prices other consumers pay, which seems implausible.

§2.4.1, we will consider a general setup to account for both these effects.

From (2.1) it follows that:

$$\theta_a = \frac{1}{2} - \frac{a_o - b_c}{2t} - \frac{\lambda \cdot \max(a_o - a_c, 0)}{2t} + \frac{\lambda \cdot \max(b_c - b_o, 0)}{2t} \tag{2.2}$$

The first two terms give the representation of the marginal consumer in the absence of fairness concerns. The last two terms reflect the shift in the marginal consumer driven by consumers' fairness concerns. In the equilibrium that poaching prices are lower than past-customer prices, we can see that if prices do not change, λ shifts θ_a to the left, i.e., the direct effect of fairness concerns is to encourage switching. However, λ also affects the past-customer price a_o and the poaching price b_c. The total impact of λ on switching will also depend on how fairness concerns affect firms' strategic pricing decisions, which in turn affects switching. We will discuss the total impact of fairness concerns on consumer switching after solving for the second period prices and present the result in Proposition 14.

The consumer who is indifferent between staying with firm B and switching to firm A is characterized by θ_b where

$$r - t(1-\theta_b) - b_o - \lambda \cdot \max(b_o - b_c, 0) = r - t\theta_b - a_c - \lambda \cdot \max(a_c - a_o, 0) \tag{2.3}$$

$$\theta_b = \frac{1}{2} + \frac{b_o - a_c}{2t} + \frac{\lambda \cdot \max(b_o - b_c, 0)}{2t} - \frac{\lambda \cdot \max(a_c - a_o, 0)}{2t} \tag{2.4}$$

Each firm's second period profits consist of profits generated by selling to the firm's past customers and the competitor's customers who the firm poaches from the competitor. Firms' profit functions in the second period are:

$$\Pi_{a2} = a_o\theta_a + a_c(\theta_b - \theta_1) \tag{2.5}$$

$$\Pi_{b2} = b_o(1-\theta_b) + b_c(\theta_1 - \theta_a) \tag{2.6}$$

In Appendix A we show that for $\theta_1 \in \left(\frac{1}{3}, \frac{2}{3}\right)$, in any pure strategy equilibrium, poaching prices must be lower than past-period prices. Furthermore, we show that for a symmetric first period pricing equilibrium, a second period pure strategy pricing equilibrium exists where $a_o^* > a_c^*$.[§] Therefore, old customers express fairness concerns as they pay higher prices than switching customers. Table 2.1 provides the equilibrium second-period prices as functions of the first period market share (θ_1). As θ_1 increases, i.e., firm A's first period market share expands, prices in this segment (a_o^* and b_c^*) increase. At the same time, firm B's first period market share shrinks, and prices in this segment (a_c^* and b_o^*) decrease. In the symmetric equilibrium, $\theta_1^* = \frac{1}{2}$ and the equilibrium prices in the second period are $a_o^* = b_o^* = \frac{2+\lambda}{3(1+\lambda)}t$, $a_c^* = b_c^* = \frac{1+2\lambda}{3(1+\lambda)}t$. It is important to note that these behavior-based prices are lower than the equilibrium price of t in the static game without price discrimination (see Lemma 3). The second period profit is $\Pi_{a2}^* = \Pi_{b2}^* = \frac{5+5\lambda-\lambda^2}{18(1+\lambda)}t$. This profit is also lower than the profit of $\frac{t}{2}$ in the static game. These results reinforce the standard finding in the literature that conditioning firm decisions on purchase history results in lower prices and profits in the second period than in the case without recognition (Fudenberg and Tirole 2000, Zhang 2011).

Proposition 1 ***(Second Period Pricing and Switching)*** *As consumers become more con-*

[§]We use this result that poaching prices are lower than past-customer prices in the rest of the paper.

cerned about fairness (i.e., λ increases), prices charged to past consumers decrease and poaching prices increase. As λ increases, fewer consumers switch.

Table 2.1: Period 2 Prices and Profits

	General Form	$\theta_1^* = \frac{1}{2}$
a_c^*	$\left[-\frac{4(1+\lambda)}{3+3\lambda-2\lambda^2}\theta_1 + \frac{9+21\lambda+10\lambda^2-4\lambda^3}{3(1+\lambda)(3+3\lambda-2\lambda^2)}\right]t$	$\frac{1+2\lambda}{3(1+\lambda)}t$
a_o^*	$\left[\frac{2(1-\lambda)}{3+3\lambda-2\lambda^2}\theta_1 + \frac{3+9\lambda+2\lambda^2-2\lambda^3}{3(1+\lambda)(3+3\lambda-2\lambda^2)}\right]t$	$\frac{2+\lambda}{3(1+\lambda)}t$
b_c^*	$\left[\frac{4(1+\lambda)}{3+3\lambda-2\lambda^2}\theta_1 - \frac{3+3\lambda+2\lambda^2+4\lambda^3}{3(1+\lambda)(3+3\lambda-2\lambda^2)}\right]t$	$\frac{1+2\lambda}{3(1+\lambda)}t$
b_o^*	$\left[-\frac{2(1-\lambda)}{3+3\lambda-2\lambda^2}\theta_1 + \frac{9+9\lambda-4\lambda^2-2\lambda^3}{3(1+\lambda)(3+3\lambda-2\lambda^2)}\right]t$	$\frac{2+\lambda}{3(1+\lambda)}t$
θ_a^*	$\frac{1-\lambda^2}{3+3\lambda-2\lambda^2}\theta_1 + \frac{3+9\lambda+2\lambda^2-2\lambda^3}{6(3+3\lambda-2\lambda^2)}$	$\frac{2+\lambda}{6}$
Π_{a2}^*	$\theta_a^* a_o^* + (1-\theta_a^*-\theta_1^*)a_c^*$	$\frac{5+5\lambda-\lambda^2}{18(1+\lambda)}t$

Intuition suggests that consumers' fairness concerns constrain the degree to which firms can price discriminate among customers. This intuition is valid. Any price difference among consumers decreases past consumers' willingness to buy from the same firm. In order to mitigate this negative impact of price discrimination, firms lower the high prices charged to past consumers and raise the low poaching prices offered to competitor's consumers, to reduce the price differential among consumers. As fairness concerns become stronger, the two customized prices get closer. If $\lambda = 1$, firms charge the same price from both the past and new customers.¶

From (2.2), it is easy to see that in the symmetric equilibrium where poaching prices are lower than past-customer prices, holding prices constant, the direct effect of fairness concerns is to encourage switching. This is intuitive as when past customers become re-

¶Note that behavior-based prices in the second period are lower than price in the static game. When $\lambda = 1$, although firms charge past and new customers the same price, this price is $\frac{t}{2}$, lower than the static price t that firms charge without customer recognition.

sentful about being price discriminated, staying with the same firm induces a disutility because of the perceived unfairness. The marginal consumer who was indifferent between staying and switching without fairness concerns now prefers to switch, because the utility of staying decreases with fairness concerns. However, in addition to this direct effect, there are opposing pricing effects. As the first part of the proposition shows, fairness concerns affect consumers' incentives to switch in three ways. First, fairness concerns reduce the incentives to switch to a competitor since the poaching prices are higher. Second, fairness concerns increase the incentives to stay with the current firm as the past-customer prices are lower. Third, by reducing the price differential between the two customized prices, firms reduce the disutility of being unfairly overcharged. These pricing effects make staying more bearable and switching less attractive, thereby encouraging past customers to stay with their current firm. These pricing effects outweigh the direct effect of fairness on inducing switching. As a result, stronger fairness concerns lead to more consumers staying with their current firm, even though they are unfairly price discriminated for their loyalty.

Proposition 2 ***(Second Period Profits)*** *As consumers become more concerned about fairness (i.e., λ increases), second period profits decrease.*

Recall that firms use uniform pricing when purchase history information is not available. The aforementioned pricing changes driven by fairness concerns appear consistent with the expected effects due to lack of customer information. It seems to suggest that fairness concerns act in the same way as lack of customer information, which also dissuades firms from price discrimination in the second period. If this is the case, we would expect that as fairness concerns become stronger, both firms poach each other's consumers less aggressively, competition becomes softer, and the second period profits increase. However, in contrast to this intuition, we find that as fairness concerns become stronger, second period profits *decrease*. In order to understand this result, note that there are two opposing effects of λ on prices. First, λ leads to higher poaching prices. This effect would increase second period profits. However, an increase in λ also leads to a decrease in the prices charged from past customers. This effect would decrease second period profits. The decrease in the past-customer price has the same magnitude as the increase in the poaching price, as $|\frac{\partial a_o}{\partial \lambda}| = |\frac{\partial a_c}{\partial \lambda}| = \frac{3t}{(1+\lambda)^2}$. However, the switcher segment is smaller than the loyal segment.[‖] Furthermore, as Proposition 14 shows, λ also leads to fewer switchers and more customers who choose to pay the past-customer price. Thus, the negative effect of decrease in the past-customers price is for a larger segment of customers which becomes larger as λ increases. Therefore, overall second period profits decrease as λ increases.

This result underlines one important difference between the impact of fairness concerns and lack customer information. In addition to the opposite effect on second period profits, fairness concerns and lack of customer information also affect the second period prices differently. Specifically, lack of customer information increases the price offered to past customers. This is because when customer information becomes available, firms poach each other's customers. As a result, firms cannot charge high prices to their loyal customers who are offered a deal by the competitor. However, when customer information

[‖]In equilibrium, $\theta_a^* = \frac{1}{3} + \frac{\lambda}{6}$, $\theta_b^* = \frac{2}{3} - \frac{\lambda}{6}$, and $\theta_1^* = \frac{1}{2}$. The size of A's loyal segment is $M_l = \theta_a^*$ and the size of A's switcher segment is $M_s = \theta_b^* - \theta_1^*$. The loyal segment is larger than the switcher segment because $M_l - M_s = \frac{1}{6} + \frac{\lambda}{3} > 0$, which is positive and increasing in λ.

becomes unavailable, such poaching is impossible and past-customer prices increase. In contrast, fairness concerns lead to lower prices charged to past customers, because past customers exhibit fairness concerns when paying the higher price than new customers who switch from the competitor. In order to mitigate fairness concerns, firms reduce the price charged to past customers. In addition, lack of customer information and fairness concerns both increase the poaching price; however, the mechanism is very different. The poaching price increases with lack of information because competition is softer without customer information. However, poaching price increases with fairness concerns because lower poaching prices increase the perception of unfairness. In order to mitigate these fairness concerns and induce past customers to buy, firms raise the poaching price. Furthermore, lack of customer information leads to lower prices and profits in the first period (Villas-Boas 1999; Fudenberg and Tirole 2000), while fairness concerns lead to higher prices and profits in the first period (see Table 2.2 for a summary of comparison between fairness effects and lack of customer information). We will analyze the impact of fairness concerns on the first period pricing and profits in the next subsection.

Table 2.2: Fairness versus Lack of Information: Relative to BBP without Fairness

	Lack of Information	Fairness Concerns
Period 2 Profits	Increase	Decrease
Past-customer Price	Increase	Decrease
Poaching Price	Increase	Increase
Period 1 Price	Decrease	Increase
Period 1 Profits	Decrease	Increase
Total Discounted Profits	Increase	Increase

2.3.2 The First Period

Now let us analyze consumer choice and firms' price competition in the first period. Consider the marginal consumer located at θ_1. This consumer rationally anticipates that he will switch firm in the second period. Therefore, his choice in period 1 is determined by prices in period 1 as well as the poaching prices he will face when he switches firm in period 2. If this consumer buys from firm A at price a_1 in period 1, he will switch to firm B at price b_c in period 2.[**] The corresponding utility in two periods is:

$$r - t\theta_1 - a_1 + \delta_c \left[r - t(1-\theta_1) - b_c(a_1, b_1) \right] \tag{2.7}$$

where $b_c(a_1, b_1)$ and $b_o(a_1, b_1)$ are the consumer's rational expectation of the poaching price and past-customer price in the second period by firm B, given the first period prices. Similarly, if this consumer buys from firm B at price b_1 in period 1, he will switch to firm A at price a_c in period 2. The utility for doing so is:

$$r - t(1-\theta_1) - b_1 + \delta_c \left[r - t\theta_1 - a_c(a_1, b_1) \right] \tag{2.8}$$

where $a_c(a_1, b_1)$ and $a_o(a_1, b_1)$ are the rational expectation of the poaching price and past-customer price that firm A charges in the second period. Since this marginal consumer at θ_1 is indifferent between these two options, the terms in (2.7) and (2.8) must be equal. Imposing the rational expectations conditions and from Table 1 it follows that (details are in the Technical Appendix A):

$$\theta_1 = \frac{1}{2} - \frac{a_1 - b_1}{2t\left(1 + \frac{1+\lambda+2\lambda^2}{3+3\lambda-2\lambda^2}\delta_c\right)} \tag{2.9}$$

[**] As is standard in the literature, we assume that the consumers have rational expectations about the future prices.

At the beginning of period 1, firms set period 1 prices a_1 and b_1 to maximize the total discounted profits generated from two periods. The profit functions are

$$
\begin{aligned}
\Pi_a &= \Pi_{a1} + \delta_f \Pi^*_{a2}(\theta_1) = a_1 \theta_1 + \delta_f \Pi^*_{a2}(\theta_1) \\
\Pi_b &= \Pi_{b1} + \delta_f \Pi^*_{b2}(\theta_1) = b_1 (1-\theta_1) + \delta_f \Pi^*_{b2}(\theta_1)
\end{aligned}
\tag{2.10}
$$

First order conditions with respect to a_1 and b_1 give the equilibrium outcome. Since results for the two firms are symmetric, we report the equilibrium results for firm A only. Table 2.3 provides the equilibrium outcome. If $\lambda = 0$, the model and equilibrium outcome reduce to those without fairness concerns as in the conventional poaching model. We have $a^*_1 = \frac{3+\delta_c}{3}t$, $a^*_o = \frac{2}{3}t$, $a^*_c = \frac{t}{3}$, $\Pi^*_a = \frac{9+3\delta_c+5\delta_f}{18}t$, $\Pi^*_{a2} = \frac{5}{18}t$, and $\theta^*_a = \frac{1}{3}$. When fairness concerns exist, i.e, $\lambda > 0$, we will analyze how the degree of fairness concerns (λ) affects firms in the first period. We will first present our findings and then explain the intuitions in detail.

Table 2.3: Period 1 Price, Period 1 Profits, and Total Discounted Profits

a^*_1	$\frac{3\delta_c(1+2\lambda+3\lambda^2+2\lambda^3)+\delta_f\lambda(7+7\lambda-2\lambda^2)+3(3+6\lambda+\lambda^2-2\lambda^3)}{3(1+\lambda)(3+3\lambda-2\lambda^2)}t$
Π^*_{a1}	$\frac{3\delta_c(1+2\lambda+3\lambda^2+2\lambda^3)+\delta_f\lambda(7+7\lambda-2\lambda^2)+3(3+6\lambda+\lambda^2-2\lambda^3)}{6(1+\lambda)(3+3\lambda-2\lambda^2)}t$
Π^*_a	$\frac{9\delta_c(1+2\lambda+3\lambda^2+2\lambda^3)+\delta_f(15+51\lambda+23\lambda^2-19\lambda^3+2\lambda^4)+9(3+6\lambda+\lambda^2-2\lambda^3)}{18(1+\lambda)(3+3\lambda-2\lambda^2)}t$

Proposition 3 ***(First Period Prices and Profits)*** *As λ increases, i.e., consumers become more concerned about fairness, first period prices and profits increase.*

The result therefore shows that while fairness concerns decrease firms' second period profits, they increase profits in the first period. Since firms split the market equally, profits increase because prices increase. Let us understand why first period prices increase with consumers' fairness concerns. Given that two firms are symmetric, let us take firm A's perspective. The derivative of firm A's total discounted profits over two periods with respect to A's first period price is

$$\frac{\partial \Pi_a}{\partial a_1} = \frac{\partial \Pi_{a1}}{\partial a_1} + \delta_f \frac{d\Pi_{a2}^*(\theta_1)}{d\theta_1} \frac{\partial \theta_1}{\partial a_1} \tag{2.11}$$

where the first term on the right hand side is the marginal impact of the first period price on the first period profits, and the second term is the marginal impact of the first period price on the second period profits through altering the first period market share. An increase in λ affects the equilibrium first period prices by directly altering the marginal impact of the first period prices on both first and second period profits. It turns out that both these effects are positive (we provide the intuition below). This implies that an increase in λ will shift the reaction curves for first period prices outward. Since prices are strategic complements, an increase in λ therefore leads to higher first period prices.

Marginal Impact of First Period Prices on Second Period Profits. Let us first consider the impact of first period prices on second period profits. In the standard symmetric poaching model, the second term $\delta_f \frac{d\Pi_{a2}^*(\theta_1)}{d\theta_1} \frac{\partial \theta_1}{\partial a_1}$ in (2.11) equals zero. This means that firms' incentive to manage their second period profits, in particular the incentive to mitigate the negative impact of customer recognition, does not affect their first period pricing strategy. This is because when θ_1 is around the center of the Hotelling line, the first period market share has no first-order effect on the second period profits.[††] Hence, (2.11) reduces

[††]This occurs because as a firm's first period market share expands, the firm in the second period will serve a larger segment of own customers and a smaller segment of competitor's customers. This market

to $\frac{\partial \Pi_a}{\partial a_1} = \frac{\partial \Pi_{a1}}{\partial a_1}$, which implies that firms set first period prices to maximize the profit generated from the first period alone. Although firms are forward-looking, firms do not shift first period prices for strategic reasons of improving second period profits (Fudenberg and Tirole 2000, Zhang 2011).

However, this result no longer holds when consumers exhibit fairness concerns. *When consumers care about price fairness, an increase in the first period market share has a negative first-order effect on the second period profits.* Aggressive pricing in the first period would lead to lower profits in the second period.

To see this, in the symmetric equilibrium, the marginal effect of the first period market share on the second period profits is:

$$\left.\frac{d\Pi_{a2}^*(\theta_1)}{d\theta_1}\right|_{\theta_1=\frac{1}{2}} = -\left[\frac{(7+7\lambda-2\lambda^2)\lambda t}{3(1+\lambda)(3+3\lambda-2\lambda^2)}\right] \leq 0 \tag{2.12}$$

where the equality holds only when $\lambda = 0$. Note that when there are no fairness concerns, we get the familiar result that second period profits are not affected by the first period market share (Fudenberg and Tirole 2000, Zhang 2011). However, in the presence of fairness concerns, i.e., when $\lambda > 0$, a firm's first period market share has a negative impact on its profit in the second period. Furthermore, this effect becomes stronger as λ increases, as can be easily seen using (2.12).[‡‡]

This effect arises because an expansion in a firm's first period market share affects the

partition allows the firm to make more profits from its own segment but less profits from the competitor's segment. When θ_1 is around the center of the Hotelling line, the marginal gains from the firm's own segment are exactly canceled out by the marginal losses in the competitor's segment. Therefore, first period market share has no direct impact on second period profits.

[‡‡]The derivative of the right hand side of (2.12) with respect to λ is $-\frac{t(12\lambda^4+4\lambda^3+17\lambda^2+42\lambda+21)}{3(1+\lambda)^2(3+3\lambda-2\lambda^2)^2} < 0$.

firm's second period pricing in two ways. First, since the firm has a larger customer base in the second period, its price for past customers to repurchase should be higher. However, fairness concerns do not allow the firm to raise this price as much as without fairness concerns. Second, given that the market is fully covered and does not expand, the firm that prices more aggressively in the first period would face a smaller competitor in the second period, and the customers to poach would lie closer to the competitor. The firm would have to poach with a lower price. However, a lower poaching price makes the price for past customers appear more unfair. By lowering the poaching price, the firm may lose past customers to the competitor and the second period profits would decline.[§§] Therefore, in the presence of fairness concerns, pricing aggressively to gain market share in the first period, negatively affects profits in the second period. Furthermore, this impact becomes stronger as λ increases. Consequently, as λ increases, firms have lower incentives to compete aggressively in the first period.

Marginal Impact of First Period Prices on First Period Profits. Now consider the impact of first period prices on first period profits. Note that without customer recognition, $\theta_1 = \frac{1}{2} - \frac{p_a - p_b}{2t}$ as in the standard static model of horizontal competition (see proof of Lemma 1 in Technical Appendix A). The marginal impact of a change in prices on sales is $\partial \theta_1^* / \partial p_a = -\frac{1}{2t}$. With customer recognition, the marginal impact of a change in first

[§§]To see how second period prices change with first period market share, we have $\frac{\partial a_o^*(\theta_1)}{\partial \theta_1} = \frac{2(1-\lambda)}{3+3\lambda-2\lambda^2} t > 0$ and $\frac{\partial a_c^*(\theta_1)}{\partial \theta_1} = -\frac{4(1+\lambda)}{3+3\lambda-2\lambda^2} t < 0$. Hence, as the first period market share increases, the second period past-customer price increases and poaching price decreases, which intensifies the perceived price unfairness.

period prices on first period sales is given from (2.9):

$$\frac{\partial \theta_1^*}{\partial a_1} = \frac{-1}{2t\left(1 + \frac{1+\lambda+2\lambda^2}{3+3\lambda-2\lambda^2}\delta_c\right)} < 0 \tag{2.13}$$

If $\lambda = 0$, i.e., fairness concerns do not exist, $|\frac{\partial \theta_1^*}{\partial a_1}| = \frac{1}{2t\left(1+\frac{\delta_c}{3}\right)} \leq \frac{1}{2t}$ and strict inequality holds as long as $\delta_c > 0$. It implies that even without fairness concerns, consumers who are not completely myopic are less sensitive to period 1 prices than without recognition (Fudenberg and Tirole 2000). To understand this result, first note that the size of the first period market share determines the poaching price that firms use. A firm which has a larger market share is more aggressive in poaching and charges a lower poaching price in the second period. In particular, in equilibrium we have:

$$a_c - b_c = \frac{4(1-2\theta_1)(1+\lambda)}{3+3\lambda-2\lambda^2}t \tag{2.14}$$

If firm A has a smaller customer base (i.e., $\theta_1 < \frac{1}{2}$), its poaching price a_c is higher than B's poaching price b_c. Consider the marginal consumer at $\theta_1^* = \frac{1}{2}$ who is indifferent between buying from A and B when both firms offer the same prices. If this consumer buys from B due to a slight increase in A's first period price, the new indifferent consumer is at $\theta_1^* < \frac{1}{2}$. Using (2.14) we see that in this case $a_c - b_c > 0$. Hence, A's poaching price a_c is larger than B's poaching price b_c and the consumer who buys from B in the first period gets the poaching price offered by A, which is a worse deal in the second period. Therefore, for forward-looking customers, a small price increase today increases the discount they receive upon switching in the next period. Consequently, anticipating better switching deals, consumers are less sensitive to an increase in first period prices. This result holds even without fairness concerns.

Now, let us examine how fairness concerns affect consumers' price sensitivity in the first period. Intuition might suggest that fairness would make consumers in the first period more price sensitive since poaching prices increase due to fairness concerns (see Proposition 1). However, this intuition is not correct and in fact, we have:

$$\frac{\partial^2 \theta_1^*}{\partial a_1 \partial \lambda} = \frac{4\delta_c \lambda (2+\lambda)}{\left(1+\frac{1+\lambda+2\lambda^2}{3+3\lambda-2\lambda^2}\delta_c\right)^2 t} > 0 \tag{2.15}$$

The above relationship implies that consumers with stronger fairness concerns are less price sensitive in the first period. The reason for this is that the marginal consumer always switches and therefore what determines his price-sensitivity is how the difference in the switching price, i.e. $(a_c - b_c)$, changes with λ. We have:

$$\frac{\partial}{\partial \lambda}(a_c - b_c) = \frac{8(1-2\theta_1)(2+\lambda)\lambda t}{(3+3\lambda-2\lambda^2)^2} \tag{2.16}$$

The above relationship implies that as fairness concerns increase, the larger firm provides a relatively better switching deal. The reason is as follows. Suppose θ_1 decreases from $\frac{1}{2}$ as a result of a slight increase in firm A's first period price. This change in market share requires the smaller firm A to raise its poaching price and the larger firm B to cut its poaching price. When consumers have fairness concerns, A has a stronger incentive to raise its poaching price than B's incentive to cut its poaching price, as a lower poaching price makes their past-customer price appear more unfair. As a result, fairness concerns lead to relatively higher switching price offered by A and better switching deal offered by B, which gives more incentives for consumers to stay with A to receive B's switching deal. Thus, an increase in fairness concerns makes consumers even less price sensitive. Consequently, an increase in fairness concerns makes the first period profits less sensitive to first period prices.

The analysis of the impact of first period prices on profits show that the effect on first period profits is driven by consumer expectations of future poaching prices while the effect on second period profits is driven by firm expectations of the negative impact of first period market share on second period profits. It is important to note the role of consumer and firm discount factors. As consumers become more patient, the marginal impact of first period profits on first period prices becomes stronger. On the other hand, as firms become more patient, the effect of second period profits on first period prices becomes more important.

It is also useful to note that in equilibrium the first period prices are higher than the second period prices, even for firm's own customers. Hence when firms conduct behavior-based pricing, prices decline over time. In particular, we have

$$a_1^* - a_o^* = \frac{3\delta_c(1+2\lambda+3\lambda^2+2\lambda^3)+\lambda\delta_f(7+7\lambda-2\lambda^2)+3+9\lambda+4\lambda^2-4\lambda^3}{3(1+\lambda)(3+3\lambda-2\lambda^2)}t > 0 \tag{2.17}$$

$$a_1^* - a_c^* = \frac{3\delta_c(1+2\lambda+3\lambda^2+2\lambda^3)+\lambda\delta_f(7+7\lambda-2\lambda^2)+6+9\lambda-\lambda^2-2\lambda^3}{3(1+\lambda)(3+3\lambda-2\lambda^2)}t > 0 \tag{2.18}$$

After discussing each of the two periods separately, we analyze the total discounted profits each firm makes over two periods. Comparing the equilibrium outcomes with customer recognition and fairness concerns in Table 2.2 and the equilibrium outcomes without customer recognition in §2.2.1, we have the following result.

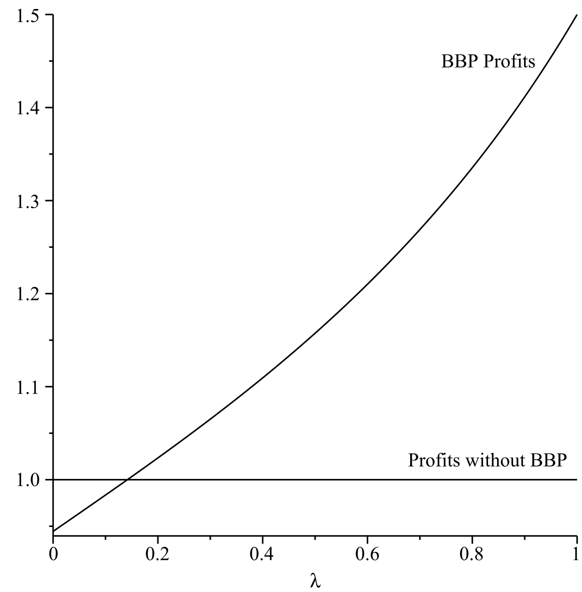
Proposition 4 ***(Total Discounted Profits)*** *When consumers' fairness concerns are sufficiently strong, firms' total discounted profits with behavior-based price discrimination exceed the total discounted profits without customer recognition.*

Existing research typically find that firms' total discounted profits with behavior-based price discrimination are lower than the total discounted profits without customer recognition (Fudenberg and Tirole 2000, Villas-Boas 1999, Acquisti and Varian 2005, Pazgal and Soberman 2008). The intuition is that when consumers reveal their preferences through buying from their preferred firms in the first period, firms offer low prices to poach the competitor's customers who reveal lower preferences. Poaching weakens firms' ability to extract surplus from their high-valuation customers and intensifies competition. As a result, profits with behavior-based poaching are lower than profits without customer recognition. This negative impact of customer recognition has also been found in contexts where firms make other dynamic decisions such as behavior-based personalization in product designs (Zhang 2011).

Here, we show that when consumers exhibit fairness concerns, behavior-based pricing can be more profitable than pricing without customer recognition. The intuition follows from the results and discussions in the two separate periods. On one hand, fairness concerns reduce firms' profits in the second period by reducing the price charged to past customers. On the other hand, fairness concerns increase firms' profits in the first period by softening price competition and reducing price sensitivity. The increase in the first period profits offsets the decrease in the second period profits and total discounted profits over two periods increase with fairness concerns[¶¶]. Furthermore, when fairness concerns

[¶¶]These results can still hold when the disutility of fairness concerns is a concave or convex function of the price difference between repeat customers and switchers. With these nonlinear functional forms, all results from the second period hold. The first period results, i.e., as fairness concerns become stronger, first period prices increase and total discounted profits exceed total discounted profits without customer recognition, can hold if the functional form is concave or not too convex (e.g., $f(x) = x^{1.1}$). With functional forms that are too

Figure 2.2: BBP Profits Vary with Fairness Concerns ($\delta_c = \delta_f$)



are sufficiently strong, i.e., $\lambda > \underline{\lambda}$, total discounted profits are higher than profits without customer recognition. In the case that $\delta_c = \delta_f$, the condition for behavior-based pricing to be profitable reduces to $\lambda > \underline{\lambda} \approx 0.14$ (see Figure 2.2). In the general case that $\delta_c \neq \delta_f$, the threshold $\underline{\lambda}$ is such that $\frac{9(1+2\underline{\lambda}+3\underline{\lambda}^2+2\underline{\lambda}^3)}{12+3\underline{\lambda}-14\underline{\lambda}^2+\underline{\lambda}^3-2\underline{\lambda}^4} = \frac{\delta_f}{\delta_c}$(see the Technical Appendix A for detailed proof).***

Now let us look at the implications of consumers' fairness concerns on consumer surplus and social welfare. We measure consumer surplus using two different approaches. In the first approach, we measure the monetary payoff of consumers without the direct

convex, first period prices and total discounted profits of behavior-based pricing can decrease with fairness concerns.

***As λ increases from 0 to 1, $\frac{9(1+2\lambda+3\lambda^2+2\lambda^3)}{12+3\lambda-14\lambda^2+\lambda^3-2\lambda^4}$ increases to infinity. The threshold $\underline{\lambda}$ decreases if consumers are more forward-looking because profits of BBP increase with both θ_c and θ_f, where the profits without customer recognition is $\frac{(1+\delta_f)t}{2}$, increasing with δ_f only and are independent of θ_c.

effect of fairness concerns on consumer utility. Note that even in this case, we incorporate the indirect effect of fairness concerns on prices. With this approach, for a customer located at θ who purchases from firm A in both periods, his surplus would be $(1+\delta_c)(r-t\theta)-a_1-\delta_c a_o$. The second approach to compute surplus is to include the fairness component, i.e, the direct disutility of being unfairly price discriminated. In this way, the customer in the previous example would receive a surplus of $(1+\delta_c)(r-t\theta)-a_1-\delta_c a_o-\delta_c\lambda(a_o-a_c)$, where the term $-\delta_c\lambda(a_o-a_c)$ captures the disutility of experiencing price unfairness in the second period. In the following discussion, to simplify exposition, we focus on the case that $\delta_f=\delta_c$ and $t=1$. In the Technical Appendix A, we show that these results hold for a broader range of parameters.

Proposition 5 ***(Consumer Surplus)*** *Consumers' fairness concerns decrease consumer surplus.*

Public policy makers aim to raise public awareness of firms' practice of behavior-based price discrimination, with the best intention of protecting consumers from being unfairly price discriminated by firms. The hope is that as consumers become more conscious about price fairness, consumers can make better choices that are good for consumers as a whole. However, such an analysis misses out on the fact that firms would optimally adjust to such changes in the environment. Once we incorporate these strategic price adjustments, we find that consumer surplus derived using both approaches *decreases* with the degree of consumers' fairness concerns. Thus, as consumers become more informed about firms' price discrimination and more concerned about price fairness, consumers as a whole are worse off.

To understand this result, first consider the monetary consumer surplus where we do not consider the disutility of fairness concerns in deriving consumer surplus. Fairness concerns affect this measure of consumer surplus in several ways. On the positive side, fairness concerns decrease inefficient switching to less preferred firms and lower the prices that past customers pay. These effects enhance consumer surplus. On the negative side, fairness concerns increase poaching prices and the first period prices. In addition, with fairness concerns, consumers who would previously switch to enjoy the lower poaching price now stay with their past firms and pay the higher price. These shifts lead to lower consumer surplus. The negative aspect dominates the positive aspect and therefore consumer surplus decreases with fairness concerns.

Incorporating the disutility of fairness concerns into the computation of consumer surplus generates two more effects. Consumers who do not switch experience the disutility of fairness concerns. As λ increases, fewer consumers switch (as given in Proposition 14). Hence, more customers would feel unfairly treated. On the other hand, as λ increases, the price difference between the past-customer price and the poaching price shrinks, which decreases the disutility of unfairness. When λ is less than $\bar{\lambda} \approx 0.47$, the negative impact dominates. If $\lambda > \bar{\lambda}$, the positive aspect dominates. However, even in this case, as λ increases, the positive aspect associated with adding the fairness component cannot outweigh the aforementioned negative changes in the monetary consumer surplus. Therefore, consumer surplus including the fairness component also decreases with fairness concerns.

Now let us analyze how fairness concerns affect social welfare. From the perspective of social planners, if firms and consumers discount future payoff at the same rate, pricing only determines the transfer between consumers and firms, and does not affect the overall welfare. In this case, the impact of fairness concerns on social welfare excludes its impact on prices. Proposition 14 shows that in equilibrium, as consumers become more concerned about fairness, fewer consumers switch. Such switching is socially inefficient because consumers switch to their less preferred firms. Since consumers' fairness concerns reduce inefficient switching, we expect that social welfare would increase with fairness concerns. This intuition is true if we compute social welfare without incorporating the disutility of fairness concerns in deriving consumer surplus. If we include the disutility of experiencing price unfairness, social welfare can increase with the degree of fairness concerns when such concerns are sufficiently strong.

Proposition 6 ***(Social Welfare)*** *Fairness concerns increase the social welfare derived based on monetary payoff. Fairness concerns increase the social welfare including the disutility of price unfairness if such concerns are sufficiently strong such that* $\lambda > \hat{\lambda} \approx 0.26$.

The intuition is as follows. Including the disutility of unfairness directly reduces social welfare. As λ increases, it does two things. First, it reduces inefficient switching which enhances the monetary social welfare. Second, it magnifies the disutility of price unfairness. When λ is small, its impact on reducing switching is not enough to offset its disutility on social welfare. In this case, social welfare decreases with λ. When λ is sufficiently large, its impact on reducing switching dominates and social welfare increases.

2.4 Model Extensions

In this section, we relax some assumptions made in the main analysis to generalize our results and seek new insights. In the base model, consumers form price perception by comparing their own price with other consumers' prices. However, we only consider fairness concerns for those consumers who pay a higher price than their peers. In addition, we modeled fairness concerns by capturing the utility loss of paying a higher price than other consumers, while the utility gain of paying a lower price than others is assumed away. In §2.4.1, we incorporate fairness concerns or utility gain for those consumers who get a favorable price relative to their peers. In §2.4.2, we consider situations where price perception is also affected by prices that consumers paid in the first period. In the base model, we assumed that all consumers exhibit the same degree of fairness concerns about price discrimination. In §2.4.3, we consider the case where consumers' fairness concerns are endogenously determined by the number of consumers who are offered a lower price to buy the same product. In §4.4.4, we allow consumers to face switching costs when they switch firms in the second period. To focus on the new insights generated by the extensions, we set $\delta_c = \delta_f = 1$ and $t = 1$. We summarize the key findings and discuss intuitions below. Detailed analysis can be found in Technical Appendix A.[†††]

[†††] In addition to these extensions, we also investigated how heterogenous fairness concerns among consumers affect our results. We show that when 14% or more consumers are aware about prices that other consumers pay and have fairness concerns, BBP can be more profitable than the case without customer recognition. Details are in the Technical Appendix §A-4.3. In addition, we extend the base model to allow consumer preferences to change over time and show that our main results still hold (see §A-4.4).

2.4.1 Consumers Who Pay Lower Prices Gain

In our base model, we captured the psychological phenomenon that past customers experience a utility loss when they pay higher prices than others. New customers receive the same product at a discounted price and may experience a utility gain for getting a deal. To incorporate this in the model, we modify the base model and allow for this possibility. Let the parameter g represent the degree of utility gain of receiving a deal. Then the marginal consumer at θ_a is characterized by:

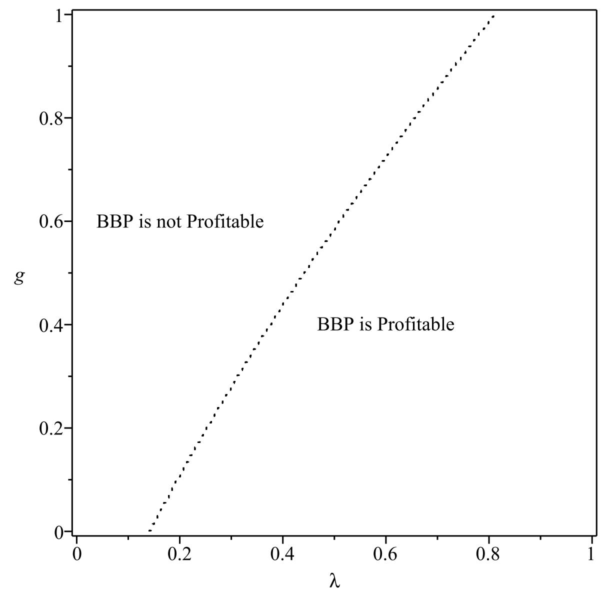
$$\begin{aligned} r-\theta_a-a_o-\lambda(a_o-a_c) &= r-1+\theta_a-b_c+g(b_o-b_c) \\ \theta_a &= \frac{1}{2}-\frac{a_o-b_c}{2}-\frac{\lambda(a_o-a_c)}{2}-\frac{g(b_o-b_c)}{2} \end{aligned} \tag{2.19}$$

where the term $g(b_o-b_c)$ is the utility gain received by the consumer when he switches to firm B and pays a lower price b_c while other consumers pay a higher price b_o for the same product. The marginal consumer at θ_b is analogously defined.

With this utility gain alone and without fairness concerns, first period market share has a *positive* effect on second period profits. This is because having a larger market share or customer base motivates the firm to charge a higher price for past customers, which enhances the gain for switching customers. Meanwhile, the larger firm faces a smaller competitor whose customers have stronger preferences for the competitor's product. In order to poach these consumers, the firm reduces the poaching price, which further enhances the gain experienced by switching customers. For these reasons, firms price aggressively in the first period for the purpose of improving second period profits. This force drives first period prices to decrease, opposite to the effect of fairness concerns that drives first period prices to increase. In addition to this effect of second period profits on first period prices, there is an opposing effect of first period profits on first period prices. Note that the marginal consumer in the first period switches firms in the second period. When getting a deal induces a gain, a decrease in firm A's market share leads to a decrease in B's poaching price to a larger degree than without the utility gain, as B has incentives to lower the poaching price to enhance the gain experienced by switching customers. The prospect of receiving a lower poaching price and a better deal makes the marginal consumer in the first period less sensitive to first period prices. This effect motivates firms to charge higher prices in the first period, against the force to reduce first period prices for the benefits of second period profits. When the strength of the utility gain is small, the impact of second period profits on prices dominates and first period prices decrease. When the utility gain is sufficiently strong, the impact of first period profits on prices dominates and first period prices increase. However, total profits with the utility gain alone are lower than profits without customer recognition.

If the utility gain of getting a deal and the utility loss of paying higher prices coexist, results in our main model still hold, though the impact of the utility loss driven by fairness concerns are softened by the presence of utility gain associated with getting a deal. Specifically, as fairness concerns become stronger, the poaching price increases and the past-customer price decreases, to a smaller degree than in the absence of the utility gain of getting a deal. This is because firms need to balance the need to manage fairness perception and the need to exploit the gain perceived by switching consumers. The benefit of fairness

Figure 2.3: BBP Profits with Utility Gain of Getting a Deal (g)



concerns on improving overall profits is attenuated by the presence of the utility gain, as the utility gain alone leads to lower profits. As consumers value the utility gain more, fairness concerns need to be stronger for behavior-based pricing to be profitable (see Figure 2.3).

In the model of Fehr and Schmidt (1999), inequity-averse consumers also exhibit fairness concerns and experience a utility loss when they receive a better deal than their peers. This can be easily modeled in the current framework by assuming that $g < 0$. Hence, an alternative interpretation of $g < 0$ is that it captures the degree of fairness concerns experienced by new customers who pay lower prices than past customers. Our analysis shows that our results become even stronger in this case. This is intuitive since the parameter g makes it even less attractive for firms to price discriminate between past and new customers, because price discrimination leads to fairness concerns and lower utility for not only past customers who pay higher prices but also new customers who pay lower prices. Therefore, the effects we identified in the base model become stronger. In such cases, behavior-based pricing can increase firms' profits in a larger range of situations.

2.4.2 Consumers' First-Period Price Serves as a Reference Price

Our main model has focused on the peer-induced fairness where peer consumers' prices serve as reference prices to judge the fairness of one's own price. Since consumers purchase repetitively over two periods, the price that a consumer pays in the first period may also influence how the consumer perceives prices in the second period. As discussed in the main model, second period prices with behavior-based poaching are lower than first period prices. Hence, consumers may experience a gain when they pay lower prices in the second period with reference to the higher prices they paid in the first period. Let γ denote the degree of this reference price effect, the marginal consumer at θ_a in the second period satisfies the condition that

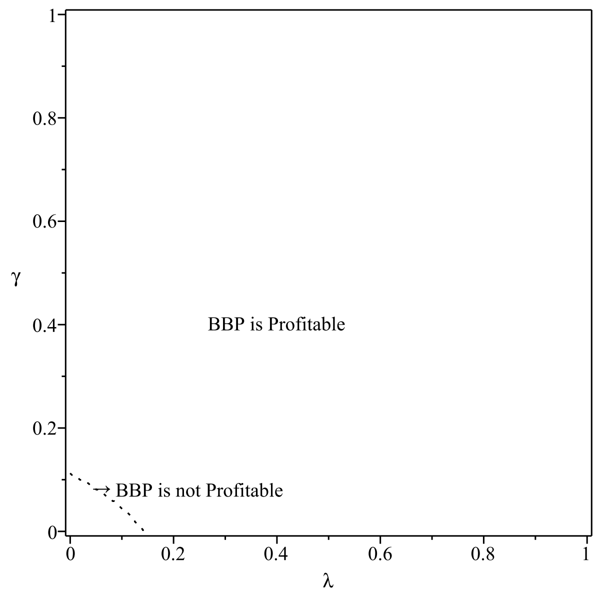
$$r-\theta_a-a_o-\lambda(a_o-a_c)+\gamma(a_1-a_o)=r-1+\theta_a-b_c+\gamma(a_1-b_c)$$

$$\theta_a=\frac{1}{2}-\frac{a_o-b_c}{2}-\frac{\lambda(a_o-a_c)}{2}-\frac{\gamma(a_o-b_c)}{2} \tag{2.20}$$

θ_b can be obtained analogously. With this reference price effect, results in our main model still hold. Moreover, as consumers value the reference gains more strongly, there is a larger range of situations for behavior-based pricing to be more profitable than without customer recognition (see Figure 2.4). This is because this reference effect alone also increases firms' total profits.

The intuition is that with first period prices as a reference price, consumers perceive

Figure 2.4: BBP Profits with Period 1 Price as Reference



the low poaching price more favorably because it offers a larger gain than the past-customer price does. As consumers value the reference gains more strongly, consumers are more motivated to switch, which leads to lower prices in the second period. Now the marginal consumer in the first period anticipates receiving a lower poaching price. First period demand becomes less sensitive to first period prices. Consequently, firms can raise first period prices to make more profits. If the reference effect does not exist (i.e., $\gamma = 0$ in Figure **??**), the model reduces to the base model. BBP is profitable when fairness concerns are sufficiently strong. As the reference effect becomes stronger, for a smaller degree of fairness concerns, BBP can be profitable. Therefore, fairness concerns operate in a more general context where historical prices impact consumers' price perceptions.[‡‡‡]

[‡‡‡]In this setup, when an old customer of firm A switches to firm B in period 2, we assume the price that the customer paid for product A in period 1 serves as the reference price. Since the two products are

It is also important to understand how fairness concerns and historical reference price impact firms differently. With the reference price alone, first period prices do not have a direct effect on second period profits if fairness concerns do not exist. This is because the first period reference price impacts perceptions of the second period past-customer prices and poaching prices to the same degree. As first period prices increase, the marginal gain from the competitor's segment is canceled out by the marginal loss in a firm's own segment even in the presence of the reference price effect. This difference underlines the distinct mechanisms through which fairness concerns and historical reference price influence firms: both effects lead to less price-sensitive demand in the first period. However, with fairness concerns, first period market share exerts a negative effect on second period profits, whereas with historical reference price alone, first period market share has no first-order effect on second period profits.

2.4.3 The Degree of Fairness Concerns are Endogenous

In our main model, we represent the degree of consumers' fairness concerns with an exogenous parameter λ. The disutility of paying a price premium $(a_o - a_c)$ is formulated as $-\lambda(a_o - a_c)$. This is consistent with the literature on fairness concerns. However, it is

differentiated, it is also possible that B's first period price may be the reference price for customers who switch from A to B. In this case, the indifferent customer at θ_a becomes:

$$r - \theta_a - a_o - \lambda(a_o - a_c) + \gamma(a_1 - a_o) = r - 1 + \theta_a - b_c + \gamma(b_1 - b_c)$$
$$\theta_a = \frac{1}{2} - \frac{a_o - b_c}{2} - \frac{\lambda(a_o - a_c)}{2} + \frac{\gamma(a_1 - b_1 - a_o + b_c)}{2}$$

The marginal consumer at θ_b can be derived analogously. One notable difference is that the first period prices impact the locations of the second period customers directly. As a result, the optimal prices in the second period are functions of first period prices. In this case, all results hold qualitatively (see §4-2 of the Appendix A for details).

plausible that a consumer may be more resentful in the case where many others receive a lower price than the case where only a few are offered a lower price. Hence, the degree of fairness concerns could depend on the number of consumers who are offered the better deal. As this number increases, consumers experience a higher level of inequity. To represent this we modify the base model. Let us consider the consumer at $\theta \leq \theta_a$. In equilibrium, this consumer chooses to stay with firm A, and he will incur fairness based disutility. Since firm A offers a switching deal to B's customers whose $\theta \geq \theta_1$, the consumer who stays with A experiences a higher level of disutility when θ_1 is lower, i.e., more consumers receive a better deal from A. Hence, the consumer's utility is

$$r - \theta - a_o - \lambda\,(1 - \eta\theta_1)\,(a_o - a_c) \tag{2.21}$$

The degree of fairness concerns is captured by $\lambda\,(1 - \eta\theta_1)$, which is decreasing in θ_1. Since $\theta_1 \in [0, 1]$, we consider $\eta < 1$ to ensure that fairness concerns still exist and induce a utility loss. Also note that if the parameter $\eta = 0$, then the model reduces to the base case. In this setup, the marginal consumer at θ_a satisfies the following condition:

$$r - \theta_a - a_o - \lambda\,(1 - \eta\theta_1)\,(a_o - a_c) = r - (1 - \theta_a) - b_c$$

$$\theta_a = \frac{1}{2} - \frac{a_o - b_c}{2} - \frac{\lambda(1 - \eta\theta_1)(a_o - a_c)}{2} \tag{2.22}$$

Similarly, the consumer who stays with firm B exhibits fairness concerns and the concerns are stronger as θ_1 increases, i.e, more consumers receive the offer from firm B. Hence, the marginal consumer at θ_b satisfies the condition:

$$r-(1-\theta_b)-b_o-\lambda\left[1-\eta(1-\theta_1)\right](b_o-b_c)=r-\theta_b-a_c$$

$$\theta_b=\frac{1}{2}+\frac{b_o-a_c}{2}+\frac{\lambda\left[1-\eta(1-\theta_1)\right](b_o-b_c)}{2} \tag{2.23}$$

Using this framework, results in our base model still hold. Specifically, as λ increases, the second period prices offered to past customers decrease, poaching prices increase, fewer consumers switch, and second period profits decline. Moreover, the total profits of BBP increase with λ and can exceed profits without customer recognition when λ exceed a threshold. It is important to note that in this setup, the first period market share θ_1 has another impact on second period profits in addition to what we have discussed in the base model. Specifically, from firm A's perspective, as θ_1 increases, it reduces the segment of competitor's consumers who receive the poaching deal and therefore softens past customers' fairness concerns. This effect generates a positive relationship between first period market share and second period profits, counteracting with the negative relationship in the base model. Our results show that for $\eta<1$, the overall impact of first period market share on second period profits is still negative, consistent with the base model.[§§§] As a result, BBP profits increase and can exceed profits without customer recognition.

[§§§] In the symmetric equilibrium, $\theta_1^*=\frac{1}{2}$. If we allow η to exceed 1 but less than 2 so that in equilibrium fairness concerns still generate a negative utility, then when η is sufficiently large, the overall impact of the first period market share on the second period profits can be positive. However, an increase in η reduces the price sensitivity of the first period consumers. The two effects of η roughly cancel out and our main result still hold (see §A-4.5 of the Technical Appendix A for details).

2.4.4 Switching Costs

Consumers may face switching costs when they switch to a new firm. Switching costs can be actual learning costs, inertia or psychological resistance to changes (Klemperer 1987a, Klemperer 1987b). Here we extend the base model by assuming that consumers incur a cost when they switch firms. Let s denote the switching cost. We assume that $s \in (0,1)$ such that some consumers have preferences that are higher than the switching costs. In this case, the marginal consumer at θ_a becomes

$$r - \theta_a - a_o - \lambda(a_o - a_c) = r - (1 - \theta_a) - b_c - s \tag{2.24}$$

$$\theta_a = \frac{1}{2} - \frac{a_o - b_c}{2} - \frac{\lambda(a_o - a_c)}{2} + \frac{s}{2} \tag{2.25}$$

Similarly, we can obtain θ_b and solve for the symmetric pure-strategy equilibrium (see Technical Appendix A for details).

When consumers who express fairness concerns also face switching costs, we find that the effects of fairness concerns on the second period prices and profits are stronger than without switching costs. The reason is that switching costs discourage consumers from switching, leading to a larger segment of past customers who experience fairness concerns. Therefore, firms need to adjust prices to a greater extent and second period profits decline more with fairness concerns. The benefit of fairness concerns on raising first period prices and profits still exist.[¶¶¶]

[¶¶¶] We can also examine the case with only switching costs by setting $\lambda = 0$. Switching costs lead to firms charging higher prices for the customers who are "locked-in" than the prices offered to the competitor's customers. These effects are directionally consistent with the impact of fairness concerns. However, it is useful to note several distinctions between the effects of switching costs and fairness concerns (see Technical Appendix A for detailed comparisons). Switching costs increase the price for past-customers who are "locked-in" with the firm and decrease the price for customers who are "locked-in" with the competitor.

2.5 Conclusion

As technology allows firms to easily track and store customers' purchase information, the practice of behavior-based pricing (BBP) is increasingly important for online and offline firms. At the same time, consumers are more knowledgeable about prices paid by other consumers and more aware of firms' practices of behavior-based price discrimination. Consumers who pay a higher price than others feel unfairly treated by firms. Price (un)fairness has become a serious concern that affects consumers' purchase decisions. In this paper, we attempt to understand how firms should adjust behavior-based pricing strategy to take consumers' fairness concerns into account. We consider a two-period model with competing firms that recognize own and competitor's customers from purchase history and poach the competitor's customers at a discounted price. Past customers pay higher prices and exhibit fairness concerns about firms' price discrimination in the second period.

We show that when consumers exhibit fairness concerns, firms can obtain higher total discounted profits from conducting behavior-based pricing than without customer recognition. This is because with fairness concerns, the first period market share has a negative first-order impact on the second period profits. This effect motivates firms to raise first period prices for the benefit of second period profits. In addition, consumers' fairness concerns reduce consumers' price sensitivity in the first period, which gives more incentives for firms to raise first period prices. As first period prices increase, first period profits in-

Consequently, switching costs increase second period profits. However, fairness concerns have the opposite impact. In addition, with switching costs, the first period market share has a positive impact on second period profits, because firms with a larger customer base can exploit the locked-in customers with higher prices and make more profits. However, with fairness concerns, the first period market share negatively impacts second period profits.

creases and drive the total discounted profits of BBP to exceed the total discounted profits without customer recognition.

We also show that consumers' fairness concerns reduce price differential and encourage consumers to stay with their preferred firms, which enhances social welfare. Finally, the growing awareness of price fairness among consumers does not benefit consumers as a whole. Instead, as consumers become more fairness-minded, consumer surplus decreases. This finding cautions public policy makers who intend to increase public awareness of firms' price discrimination practices in order to protect consumers. Such actions may raise consumers' consciousness about price unfairness, but hurt all consumers when firms adjust their BBP strategies to respond to consumers' fairness concerns.

In our theoretical analysis, we only considered one decision variable, namely price. In practice, firms can offer products of customized quality or customized services to customers based on revealed preferences in purchase history. Therefore, it would be useful to explore how fairness concerns influence consumers' buying decisions and firm's quality and price offerings. It would also be interesting to investigate the implications of fairness concerns on firms' other strategies. Lastly, researchers can empirically test how fairness affects consumer decisions in various contexts. It would be interesting to incorporate consumers' fairness concerns and empirically assess the profitability of behavior-based targeting in the presence of fairness concerns.

3 CONTEXT-DEPENDENT PREFERENCES AND PRODUCT UPGRADE

3.1 Introduction

Extensive behavioral research has established that consumers exhibit context-dependent preferences (Huber et al. 1982; Simonson 1989; Simonson and Tversky 1992; Tversky and Simonson 1993; Brenner et al. 1999; Ravi et al. 2000). When consumers evaluate a product, they consider not only the intrinsic value of the product, but also the relative standing of the product in relation to products that other consumers use in the choice context. Compared to other consumers, consuming a superior product induces a psychological gain while consuming a superseded product induces a psychological loss.

In product categories characterized with frequent product upgrades, context-dependent preferences influence consumers' overall satisfaction with products and the influence changes dynamically as firms introduce upgrades. When firms first introduce a new product, relative to consumers who have not adopted the product, early adopters may experience a psychological gain from using the new product that signals social status and openness to new technology (Jerpi 2012; Rao and Schaefer 2014). As new technology becomes available, firms introduce upgraded version of the product. Consumers may buy the upgraded product to enjoy the prestige of using the most advanced product, relative to consumers who use the older model and consumers who have not adopted the product (Thompson and Norton 2011). At the same time, compared to consumers who use the upgrade, those who continue using the older model may feel less satisfied with their product. The value of the older model decreases not because of a depreciation in the product's intrinsic value per se but by the rapid change in its context, i.e., introduction of a superior product. Similarly, consumers who do not own the product may feel pressured to buy to keep up with the latest technology and avoid the psychological loss of falling behind.

3.1.1 Research Questions

Product upgrades are prevalent in a wide range of industries. For example, software manufactures launch new versions of softwares, mobile phone providers introduce new generations of devices. Product upgrades are also prevalent in industries such as personal computers, video games, and consumer electronics. Given the important influence of context-dependent preferences on consumers' experience in the context that firms introduce upgrades, we need to understand the following questions: (1) How would context-dependent preferences affect consumer choice when firms introduce successive generations of products? (2) How should firms adjust upgrade introduction strategy to take consumers' context-dependent preferences into account? Would context-dependent preferences motivate firms to introduce high-cost major upgrades or low-cost small upgrades? (3) How would firm's dynamic pricing strategy change under context-dependent preferences? (4) How would context-dependent preferences affect firm's overall profits, consumer surplus and social welfare? (5) How would context-dependent preferences affect a firm's upgrade pricing policy? In the presence of context-dependent preferences, should firms offer a discounted price for existing users of the firm's older model to upgrade? Despite the importance of these questions, there is almost no research which has examined firm's upgrade introduction strategy under context-dependent preferences to shed light on these questions. The objective of this paper is to attempt to fill this research gap.

Researchers have been interested in studying durable-good firm's upgrade decision. One interesting focus of this stream of research is on firm's commitment problem. Specifically, when new technology becomes available for improving product quality, firm ex post sells upgrades to increase profits. However, strategic consumers anticipate the future arrival of upgrades, by-pass the base product, and wait for the upgrade. In this case, firm would ex ante be better off if it can commit to not introducing upgrades. However, lack of ability to make a credible commitment, firm's overall profit decrease. Researchers have investigated solutions to this commitment problem by augmenting firm's strategy space, such as through offering sufficiently high quality into the base product in the first period (Choi 1994), leasing the base product in the first period (Waldman 1996), or offering free upgrade warranty for consumers who buy the base product (Sankaranarayanan 2007). Our paper attempts to add to this stream of research by augmenting consumers' utility function, incorporating consumers' context-dependent preferences into the standard utility function. We show that context-dependent preferences can resolve the firm's commitment problem by rendering future introduction of upgrades unprofitable, thereby increasing firm's overall profits.

3.1.2 Preview of Model and Findings

To address these questions, we build a game theoretic model, in which a durable-goods monopolist sells successive generations of a product to consumers with continuous and heterogenous valuations for quality*. We use a standard two-period model in which the firm sells a base version of the product in period 1 and has the option of introducing an upgraded version of the product in period 2†. Consumers decide whether to buy the base product in period 1 and whether to buy the upgrade in period 2. We first examine the firm's upgrade strategy in the benchmark model in which consumers' preferences are context-independent. This benchmark model represents the classic economic model that assumes away contextual comparisons and the resulting utility of comparative gains and losses. Building on this benchmark model, we investigate how the firm's upgrade strategy changes when consumer choice is influenced by context-dependent preferences. In this case, we allow the utility that consumers derive from a product to include two components: the context-independent utility as in the benchmark model, and the context-dependent utility arising from the psychological gains and losses in comparison to other

*We consider context in which technology innovation dictates the sequential introduction of successive generations of improved products over time (Norton and Bass 1987; Levinthal and Purohit 1989; Dhebar 1994; Kornish 2001; Bulow 1982; Fudenberg and Tirole 1998; Lee and Lee 1998). In other words, firm does not have the technology to produce the upgraded product prior to period 2. For example, technological improvement in designing computer chips allow new generations of computers to increase speed and power. Restricting our consideration to such context focus our analysis on firm's decision to introduce upgrades in period 2 rather than the decision to introduce products simultaneously or sequentially (Moorthy and Png 1992). In §3.6.4, we will consider the case that firm can offer two products in a period.

†The two-period setting has been widely used in the literature to capture the durable nature of the product and the dynamic impact of firm decision (see for example Bulow 1982; Dhebar 1994; Desai and Purohit 1998; Kornish 2001; Desai et al. 2004; Fudenberg and Tirole 1998; Lee and Lee 1998; Ellison and Fudenberg 2000; Bala and Carr 2009). In §3.6.5, we will discuss the implications of context-dependent preferences in a setting with more than two time periods.

consumers' choices in the context.

We find several interesting results. We show that when the cost of introducing upgrades is low, the firm is more likely to introduce upgrades with minor quality improvement and sell them to low-valuation consumers who did not buy the base product in period 1. When the cost is high, the firm would only introduce upgrades with major quality improvement and also sell the upgrades to existing consumers of the firm's base product. In particular, context-dependent preferences motivate consumers who do not own the base product to buy upgrades while discouraging existing consumers to do so. The reason is that introducing an upgrade affects consumers' context-dependent preferences in two counteracting ways, and the relative strength of the two effects varies for the two types of consumers. First, introducing an upgrade shifts the reference quality upward, which reduces the comparative utility of the base product and increases the comparative dis-utility of forgoing consumption. This *reference quality effect* increases the comparative appeal of the upgraded product. However, consumers with context-dependent preferences are also more sensitive to prices. This *reference price effect* occurs because relative to consumers who do not buy the upgrade, paying the price of the upgrade imposes a psychological loss above and beyond the economic cost of the purchase. This increased price sensitivity hurts the firm's profit from selling the upgrade as the firm cannot charge prices as high as it does without this effect. For consumers who do not own the base product, as the reference quality increases upon the arrival of the upgrade, the loss for not using any products outweighs the loss for paying for the upgrade. Hence, the reference quality effect dominates the reference price effect, motivating these consumers to buy the upgrade. In contrast, for existing consumers who own the base product, even though the arrival of the upgrade reduces the relative value of the base product, using the base product is still in the gain domain. However, for these consumers, purchasing the upgrade induces a loss. Since losses loom larger than gains, the reference price effect dominates the reference quality effect. As a result, existing consumers with context-dependent preferences are less willing to purchase the upgrade.

Our results also show that firm's overall profits can increase due to context-dependent preferences, even when its profits from selling an upgrade decrease. The intuition is that firms may suffer from a commitment problem: ex post firms prefer to introduce upgrades, but strategic consumers anticipate this and wait for the upgrade, which makes it ex ante more profitable for firms not to introduce upgrades. Context-dependent preferences can resolve this commitment problem by rendering future introduction of upgrades unprofitable. As a result, the firm obtains a higher profit from selling the base product over time than the profit it can receive by selling sequentially upgraded products. We also find that context-dependent preferences can improve consumer surplus. This occurs when consumers' loss aversion is not too severe. In a subset of this region, consumers' context-dependent preferences also increase social welfare. Finally, we show that the upgrade pricing policy, i.e., selling upgrades to existing consumers at a discounted price, is not always a preferred upgrade policy when consumers exhibit context-dependent preferences. This is because offering a low upgrade price can reduce the reference price, imposing a loss for new consumers who buy the upgrade at the higher new-user price[‡]. As a result, fewer new consumers would want to buy the upgrade, and the overall profit of selling the upgrade could decrease. We extend our model in several directions. We consider alternative assumptions of reference formation, a model with more than two time periods, endogenous quality improvement, and a setting that technology for introducing the upgrade is available so that the firm offers two products in the first period. We show that our main results are robust to these extensions and discuss new insights.

3.1.3 Contributions

Our findings have important managerial implications. First, we help explain how context-dependent preferences influence consumer choice, an insight relevant to the wide range of industries characterized with frequent product upgrades. Second, we point out that the presence of context-dependent preferences has a significant impact on a firm's optimal upgrade introduction. In particular, after accounting for context-dependent preferences, the firm should be more aggressive in introducing low-cost upgrades and more conservative in introducing high-cost upgrades than in the absence of context-dependent preferences. Thus, our findings show that context-dependent preferences encourage low-cost evolutional rather than high-cost revolutionary advancement in product design. Third, we show that although the firm can extract surplus from existing consumers by offering them a separate upgrade price, the firm may want to abandon this upgrade pricing policy

[‡]The low-valuation consumers start to buy the firm's product in period 2. Therefore, we call these consumers "new consumers". They are low-valuation consumers who do not buy the base product in period 1. They are new to the firm rather than new to the market. New and existing consumers are endogenously determined by the firm's pricing and upgrade strategy in the model.

after taking consumers' context-dependent preferences into account. From the perspective of public policy makers, our results show that context-dependent preferences can increase consumer surplus and social welfare as long as consumers' loss aversion is not too severe. This finding suggests that education programs that help consumers with a strong loss aversion trait to reduce loss aversion using techniques such as emotion regulations need not always be beneficial (Sokol-Hessner et al. 2012).

This paper contributes to the literature in several important aspects. First, we examine a firm's optimal upgrade introduction strategy when consumers exhibit context-dependent preferences. We show that the presence of context-dependent preferences leads to a larger range of situations for firms to introduce low-cost upgrades and a smaller range of situations for firms to introduce high-cost upgrades. Second, our results reveal that context-dependent preferences can resolve a firm's upgrade commitment problem, enabling the firm to obtain higher total profits. Third, we show that offering upgrade pricing policy may not always be optimal if consumers exhibit context-dependent preferences. These findings add new insights to existing research on durable-good monopolist's upgrade strategy and context-dependent preferences. Lastly, this research also adds to the growing marketing literature that incorporates consumers' psychological behaviors to enrich standard economic models and examine firms' strategies (see for example, Amaldoss and Jain 2005; Villas-Boas 2009; Kuksov and Villas-Boas 2009; Chen et al. 2010; Guo 2014).

The rest of the paper is organized as follows. We will first review the related literature in §3.2. We introduce the model setup in §4.3. In §3.4, we solve for the firm's optimal upgrade introduction in the benchmark case where consumers do not exhibit context-dependent preferences. In §3.5, we incorporate context-dependent preferences in the firm's upgrade decision. §4.4 extends our base model and verifies the robustness of our results. We conclude with managerial implications and directions for future research in §4.5.

3.2 Related Literature

This paper is closely related to research that examines how context-dependent preferences affect firms' marketing strategies. In the traditional economic model, the utility that consumers derive from a product is a function of only the attributes of the product itself, and is invariant across context and independent of the attributes of the other alternatives. Optimal strategies derived under this assumption may not hold when preferences change with context. For this reason, researchers have shown increasing interest in examining firms' optimal strategies that incorporate context-dependent preferences. Orhun (2009) studies a monopolist's product line design when consumers' valuation for a product depends on its attributes relative to the other products in the choice context. Chen and Turut (2013) investigate firms' innovation strategy, i.e., whether a late entrant should innovate on a product's key performance dimension or on new performance dimension. They found that context-dependent preferences may encourage the follower to innovate on the new performance dimension and the firm would not do so without context-dependent preferences. Rao and Turut (2013) study how context-dependent preferences impact firms' incentive to preannounce future products. They show that context-dependent preferences dissuade a monopolist or a low-quality firm in a duopoly from preannouncing future products while motivating a high-quality firm to preannounce future products. Our work differs from their study in two ways. First, we examine firm's decision to introduce future (upgraded) products whereas they examine preannouncement decision given that future products will be introduced. Second, we are interested in situations where consumers who buy the base product can also buy the upgrade, which is not investigated in their model. Wang and Kuksov (2013) examine how competing firms' pricing strategy is affected by consumers' loss aversion when consumers incur a cost in searching for lower prices. They found that loss aversion can result in higher profits for firms. Lim (2010) studies optimal contest design when contestants care about their contest outcomes relative to other contestants. To summarize, the stream of research on context-dependent preferences has not examined the impact of context-dependence on firm's product upgrade strategy, which is the focus of this paper.

Our work is also related to the research on product upgrades. Bulow (1986) examines a monopolist's product durability decision. He shows that the firm may introduce new products too often and in order to mitigate this problem, the firm can shorten the durability of its product from the socially optimal level. Levinthal and Purohit (1989) examine the optimality of strategies such as limiting sales, buy-backs, and announcements of future upgrades. They model the decrease in an old product's value by the degree of competition between the new and the old products. In contrast to this research, we examine the impact of context-dependent preferences on upgrade strategy. Interestingly, when we incorporate context-dependence the value of the base product decreases in its comparative value upon the arrival of an upgraded product, even though the functional value of the base product remains unchanged. Therefore, the extent to which preferences for an older product decrease over time is endogenously determined by the quality improvement that the upgrade represents. Our framework is particularly relevant in today's marketplace where consumers purchase upgrades before their old products wear out.

Moorthy and Png (1992) study when a seller facing two segments of consumers with different valuations of quality should introduce high and low end products sequentially or simultaneously. They showed that sequential introduction is preferred when cannibalization is a problem and customers are relatively more impatient than the seller. Padmanabhan et al. (1997) showed that when consumers are uncertain about future network base of a high-technology product, under-provision of introductory quality serves as a signal of high externality and upgrades implement this signaling strategy. Unlike these studies, we study the firm's decision as to whether to introduce an upgrade after introducing a base product. In our model, technological improvement is exogenous and takes place over time and technology required for producing the upgrade product is not available in period 1 (see similar set up in Dhebar 1994; Kornish 2001).

Sankaranarayanan (2007) examines a firm's decision to upgrade a durable product that is backward compatible. He shows that by offering consumers who purchase current products a free upgrade can alleviate a firm's commitment problem. However, the author does not consider consumers' context-dependent preferences and its implications on the profitability of introducing upgrades. We show that the firm's commitment problem can be mitigated by the presence of context-dependent preferences. Furthermore, offering a low upgrade pricing (such as free upgrades) for existing consumers to upgrade can be detrimental as it penalizes new consumers who buy the upgrade at a higher new-user price. When the quality improvement in the upgrade is low and consumers are sufficiently loss averse, the firm would want to abandon this upgrade pricing policy.

This paper is also related to literature about Coase conjecture for durable goods. Coase proposed that when consumers rationally expect that prices will decline, consumers strategically postpone purchase, which decreases the firm's profit from using intertemporal price discrimination. The firm can be better off if it commits to sell the product always at the same price. Researchers have formally examined Coase's conjecture and its implication on dynamic pricing and product introduction. Dhebar (1994) models a durable-goods monopolist selling sequential versions of a product in a two-period model without second-hand markets. In his model, the monopolist sells only Version 1 in period 1 and Version 2 in period 2. He shows that no equilibrium exists if technological change is too rapid. Kornish (2001) uses a similar set up and shows that equilibrium exists as long as the firm does not offer any upgrade pricing, i.e., special pricing for customers who have purchased previous versions. Unlike this stream of literature, we study a different type of commitment problem, namely the firm cannot commit to not introducing upgrades. In anticipation of future upgrades, consumers could withhold purchase of the current product and wait for the upgrade. This strategic consumer behavior can decrease the firm's total profit.

3.3 Model Setup

We consider a two-period model in which a risk-neutral monopolist sells a durable product[§] [¶]. Two-period model has been commonly used to capture the durable nature of the product and to analyze the inter-temporal incentives of consumers and firms (for example Bulow 1982; Dhebar 1994; Desai and Purohit 1998; Kornish 2001; Desai et al. 2004; Fudenberg and Tirole 1998; Lee and Lee 1998; Ellison and Fudenberg 2000; Bala and Carr 2009). Researchers have also adopted two-period model to study optimal leasing and selling strategy (Desai and Purohit 1998) and channel coordination (Desai et al. 2004). In §3.6.5, we will discuss the implications of context-dependent preferences in a model with more time periods. The product is characterized with a single attribute that is denoted by quality.

In the first period, the firm sells a base model of the product. Quality of the base product is q_0 that does not depreciate over time.[‖] We normalize q_0 to 1. In the second period, new technology becomes available which allows the firm to introduce an upgrade i.e., an enhanced model of the base product. The assumption that firm can only introduce the

[§]Studying the setting of a monopoly is a natural first step (see Coase 1972; Bulow 1986; Levinthal and Purohit 1989; Waldman 1996; Desai and Purohit 1998; Fudenberg and Tirole 1998; Lee and Lee 1998; Ellison and Fudenberg 2000; Bala and Carr 2009). Our analysis focuses on the impact of context-dependent preferences on firm's upgrades decision without competition. This analysis applies for industries or local markets in which one firm dominates as well as situations where consumers exhibit strong brand loyalty and rarely switch to a competitor.

[¶]We consider situations in which firms sell rather than lease products to consumers, which is consistent with observations of firm practice in many high-technology industries such as computers, softwares, electronics, and telecommunication devices. Although we do not explicitly model leasing, prior research has shown that a durable-goods monopolist might prefer to sell rather than lease because of a moral hazard problem concerning consumer maintainable decision (Waldman 1996; Mann 1992).

[‖]In durable-good industries, upgrades are sometimes introduced rapidly before the functionality of the base product depreciates. In such cases, it is reasonable to assume that depreciation is negligible for consumers' and the firm's decisions.

upgrade in the second period has been commonly used in related research (see for example Norton and Bass (1987); Levinthal and Purohit (1989); Dhebar(1994); Kornish (2001)). Researchers have studied firm's decision to introduce high-end product simultaneously or sequentially when technology is available in period 1 (see Moorthy and Png 1992; Padmanabhan et al. 1997). We differ from these studies by focusing on firm's decision to introduce upgrades when technology shocks take place after period 1 and technology dictates the firm to introduce successively improved generations of products sequentially. In §3.6.4, we will extend the model to consider the case that firm can introduce the upgraded product in period 1. Quality of the upgraded product is $1+w$, where w is the quality improvement over the base product. The upgraded product is consumed in the second period. The fixed cost involved for introducing the upgrade is c[**].

Given that markets of durable products such as mobile devices, automobiles, and personal computers are mature, enhancements in upgrades primarily strengthen the current functionality rather than create innovative features (Today 2013). For example, Apple's new iPhone 5 was featured as larger, lighter, and faster (Delevett et al. 2012), Sony's PlayStation 3 gaming console had a few minor upgrades such as fixing wireless headset users' audio issues (Mlot 2012). For this reason, we consider $w < \frac{1}{2}$, i.e, the magnitude of quality improvement is less than half of the utility from the base product. We assume

[**] We allow c to be independent of w to simplify notation and analysis. Alternatively, we could define $c(\cdot)$ to be a convex and increasing function of w to show that the fixed cost of introducing an upgrade increases with the amount of quality improvement. This formulation can further enhance our main finding as we will show that with context-dependent preferences, firm's profits from introducing large upgrades decrease and profits from introducing small upgrades increase. With the convex cost function $c(w)$, as w increases, the increasing cost drives the profits of introducing large upgrades to decrease even more. When w is close to 0, $c(w)$ is small and profits for introducing small upgrades can still increase with context-dependent preferences. Therefore, the qualitative nature of our results still holds.

that w is exogenous. This assumption reflects the fact that the extent to which a firm can improve its product is constrained by technology. Only as technology advances and knowledge accumulates over time, can the firm offer better quality products (Krishnan and Ramachandran 2011). By assuming w to be exogenous, we abstract away from the firm's R&D decision, and therefore, focus our analysis on the firm's upgrade introduction decision. We will relax this assumption and allow the firm to choose w in §3.6.3. We also assume that the firm only sells one version of the product in a period as operating two product lines is costly (Levinthal and Purohit 1989) and therefore the firm would not sell the base model once upgrade becomes available. This assumption implies that if the firm introduces the upgraded product, it withdraws the base product and sells only the upgraded product in that period, which is consistent with practice in many industries such as automobiles, personal computers, and software (Bala and Carr 2009). If the firm does not introduce the upgraded product, it sells the base product in two periods. We assume that if a consumer purchases a new product in the second period, the old product is scrapped and of no value in the second period (Dhebar 1994; Lee and Lee 1998; Kornish 2001). This is common in product categories with rapid technology innovations such as software[††].

3.3.1 The Firm

The firm makes a product upgrade decision and sets prices in both periods. In particular, in the beginning of period 1, the firm sets the period 1 price to maximize the total

[††] Firms may offer buy-back and trade-in policies. Such policies lower the upgrading prices for existing users of the firm's product to buy the upgraded product. We will extend the model to consider such policy in §3.6.1.

profit over two periods. In the beginning of period 2, the firm first decides whether to introduce an upgraded product or continue selling the base product. After making this upgrade decision, it sets the period 2 price to maximize the period 2 profit. We assume that in each period, the firm does not price discriminate among consumers. In other words, in each period, the firm sells the product to existing consumers and new consumers at the same price (Waldman 1996). One could argue that firms sometimes offer discounted prices for existing users to buy the upgrade, such as through a special upgrade pricing policy, trade-in, or buy-backs. In §3.6.1, we extend our base model to account for this possibility. We assume that the firm has same constant marginal costs for both products, in order to focus on how the firm's upgrade strategy changes with context-dependent preferences rather than changes in production costs (see Rao and Turut 2013). Without little loss of generality, the constant marginal costs are set to zero (Levinthal and Purohit 1989; Lee and Lee 1998)[‡‡].

3.3.2 Consumers

The firm serves risk-neutral consumers with unit mass 1. Consumers are heterogenous in their valuation of quality. Let θ index a consumer's valuation for quality. Without context-dependent preferences, the indirect utility that the θ-type consumer derives from purchasing a product of intrinsic quality q sold at price p is

$$U^c(p,q;\theta) = \theta q - p \tag{3.1}$$

We model consumer heterogeneity by assuming that θ is uniformly distributed in $[0,1]$. The term $U^c(p,q;\theta)$ represents the context-independent utility enjoyed by the consumer

[‡‡]This assumption is of little loss of generality because prices are interpreted as being net of constant marginal cost.

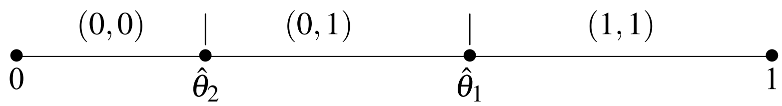
in the traditional economic model that assumes away any contextual effects. We denote this utility the *consumption utility*, as it represents the utility derived from merely consuming the product independent of context. If a consumer does not purchase any products, he receives an outside good whose consumption utility is normalized to 0. When a consumer's total consumption experience is influenced by the relative standing of the product in the choice context, in addition to the consumption utility, consumers also experience a context-dependent utility. We will discuss this context-dependent utility in §3.5.

We assume that consumers form rational expectations about their future actions and the firm's decisions. In other words, consumers expectations are fulfilled in equilibrium. This assumption has been widely used by marketing researchers to study consumers' strategic responses to firms' decisions (see for example, Levinthal and Purohit 1989; Amaldoss and Jain 2005; Sankaranarayanan 2007). Lastly, to simplify notation and analysis, we set the discount factors of the firm and consumers to 1.

3.3.3 Consumption Patterns

If the firm does not introduce upgrades, the equilibrium consumption pattern consists of three choices (see Figure 3.1). First, some consumers buy the base product in period 1 at the price p_1 and use it for two periods. We denote this choice by $(1,1)$. The quality of the base product is 1 and its price p_1 is paid in period 1 only. For this case, the consumption utility is $\theta - p_1$ in period 1 and θ in period 2. Second, some consumers wait to buy the base product in period 2. Consumers may be willing to wait if prices decline over time (Coase 1972). For example, Apple unveiled the first generation of iPhone for \$599 (8 GB). A few

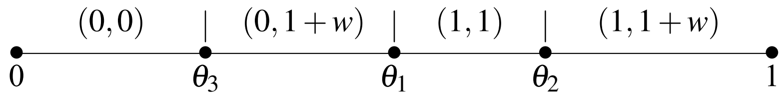
Figure 3.1: Consumer Choice Pattern Without Upgrades



months later, Apple slashed this price by \$200 (Robertson and Wong 2007). Consumers who are unwilling to pay \$599 can buy this phone at the reduced price after waiting. We denote this option by $(0,1)$. The consumer who waits receives a consumption utility 0 in period 1 and $\theta - p_2$ in period 2, where p_2 is the product's price in period 2. Third, some consumers do not buy the product. We denote this option by $(0,0)$. The consumption utility of this choice is 0 in each period. The consumption pattern that reflects these three choices is shown in Figure 3.1. In this situation, consumers with higher valuations buy earlier. Specifically, the consumer whose $\theta > \hat{\theta}_1$ buys in the first period, the consumer whose $\hat{\theta}_2 < \theta < \hat{\theta}_1$ buys in the second period, and the consumer with a smaller θ does not buy. The firm makes profit in the second period by selling the base product to consumers in the region $(\hat{\theta}_2, \hat{\theta}_1)$.

If the firm introduces an upgrade, four consumer segments can arise. First, some consumers who buy the base product in period 1 can also buy the upgraded product in period 2. The consumption utility is $\theta - p_1$ in period 1 and $\theta(1+w) - p_2$ in period 2. Second, some consumers buy the base product only. They buy the base product in period 1 and use it over two periods. The corresponding consumption utility is $\theta - p_1$ in period 1 and θ in period 2. Third, some consumers choose not to buy the base product in period

Figure 3.2: Consumer Choice Pattern A With Upgrades



1, waiting to buy the upgraded product. Then the consumption utility is 0 in period 1 and $\theta(1+w)-p_2$ in period 2. Lastly, consumers can forego consumption completely. Again, the consumption utility for doing so is 0. We denote each choice by (x,y) where x and y represent the quality of the product consumed in two periods separately.

Depending on the value of w, two consumption patterns can emerge. Figure 3.2 depicts the pattern in which all four consumer segments arise. In this pattern, the firm makes profit in period 2 by selling the upgraded product to two types of customers: new consumers in the region (θ_3,θ_1) who have relatively low valuations for quality and did not purchase the base product, and existing consumers in the region $(\theta_2,1)$ who have the highest valuations for quality and have purchased the base product in period 1. When w is sufficiently large and the price of the upgrade is sufficiently low, existing consumers purchase the upgrade to replace their base product. Alternatively, if w is small, the firm can price the upgrade such that only new consumers buy the upgrade[§§]. The corresponding consumption pattern is shown in Figure 3.3. In this case, the firm makes profit in period 2 by selling the upgrade only to new consumers in the region (θ_3,θ_1).

[§§]New consumers refer to consumers who did not buy the base product in period 1 but buy the upgrade in period 2. These consumers are located in the region (θ_3,θ_1) and are new to the firm in period 2.

Figure 3.3: Consumer Choice Pattern B With Upgrades

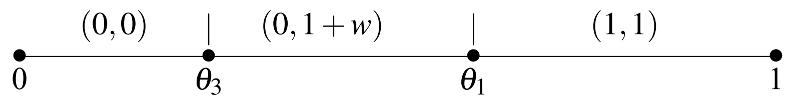
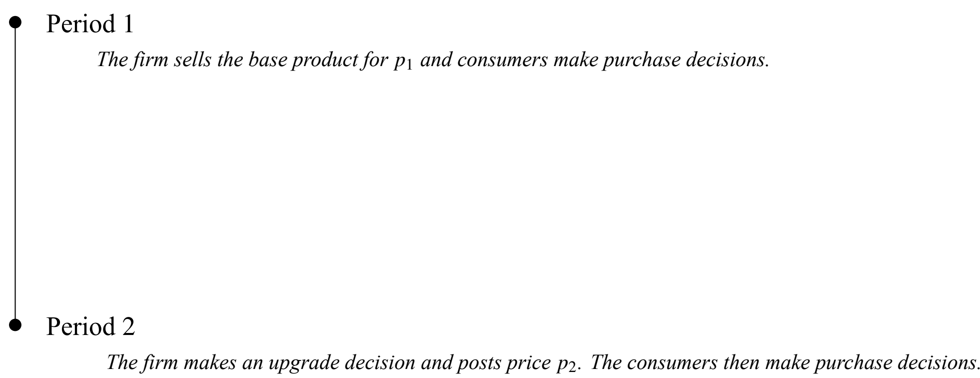


Figure 3.4: Timing of the Game



3.3.4 Timing of the Game

The timing of the game is shown in Figure 3.4. In period 1, the firm posts the price of the base product, and all consumers simultaneously decide whether to purchase the base product. Period 2 consists of three stages. First, the firm decides whether to introduce an upgraded product. Second, the firm posts the price of the product that it decides to sell. Third, consumers decide whether to purchase the product. We derive the sub-game perfect equilibrium by solving the game backwards. Details are included in the Technical Appendix.

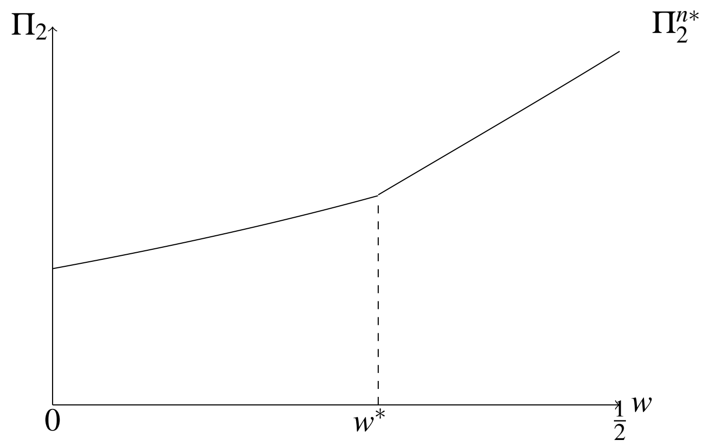
3.4 Benchmark Case

We start by analyzing the benchmark case in which consumer preferences are context-independent. In this setting, we analyze the firm's optimal upgrade strategy. It is important to note that the upgrade decision is made by the firm at the beginning of period 2. Introducing an upgraded product is optimal if selling it yields a higher profit than selling the base product. The following proposition gives the condition under which introducing an upgrade is optimal.

Proposition 7 ***(Benchmark Model)*** *In the absence of context-dependent preferences, as long as the cost of upgrade introduction is not too large, there exists a threshold of* w *such that the monopolist introduces an upgrade if and only if* w *exceeds this threshold.*

This proposition shows that as long as the fixed cost c is not too large, the firm should introduce an upgrade if the degree of quality improvement exceeds a threshold. In fact, if introducing an upgrade is costless ($c = 0$), the firm in period 2 would always prefer selling an upgrade over selling the base product. This is because the upgraded product has a higher quality than the base product. Since the willingness to pay for the upgrade is higher, the firm can charge a higher price when it sells an upgrade. In addition, when consumers anticipate that the upgrade will be introduced in period 2, fewer consumers purchase the base product in period 1 and more wait to buy in period 2. This shift in demand further increases the profit in period 2. A higher quality improvement (w) leads to a larger increase in willingness to pay. More consumers are motivated to wait for an upgrade with a larger quality improvement (w). Therefore, a higher w also leads to a greater shift in demand.

Figure 3.5: Period 2 Profit Varies without Context Dependence



Hence, the period 2 profit (denoted by Π_2^{n*} in Figure 3.5) is increasing in w. When $c > 0$, w needs to exceed a threshold to offset the cost for introducing the upgrade to be profitable. When w is small ($w < w^*$ in Figure 3.5), the firm prices the upgrade so that consumers who own the base product would not upgrade. The firm maximizes profit by selling the upgrade to new consumers only. When w is sufficiently large ($w > w^*$), the firm obtains a higher profit by selling the upgrade to both new and existing consumers.

3.5 With Context-Dependent Preferences

In this section we examine how the firm's optimal upgrade strategy changes when consumers exhibit context-dependent preferences. When consumer preferences are influenced by choice context, in addition to the consumption utility, consumers also obtain a *context-dependent utility* from making a choice. The context-dependent utility is derived from the relative standing of a product compared to the other alternatives in the market.

Prior researchers have formulated this contextual comparison by forming a context-specific reference point, in relation to which choices are framed as gains and losses (Orhun 2009; Chen and Turut 2013; Rao and Turut 2013; Lim 2010). On the quality dimension, consuming a product with a quality that is higher than the reference quality induces a psychological gain (Hardie et al. 1993). The psychological gain reflects the incremental satisfaction above and beyond the enjoyment derived from using the product independent of other alternatives in the context. For example, consumers who use the latest version of smart phones feel prestigious in comparison to other consumers who use older versions or who do not own a smart phone. Similarly, on the price dimension, in addition to the economic loss, paying a price that exceeds the reference price in a choice context induces a psychological cost. Prior research has provided evidence of this reference price effect (see for example, Monroe 1973; Winer 1986; Jacobson and Obermiller 1990; Putler 1992; Rajendran and Tellis 1994; Kalyanaram and Winer 1995; Mazumdar et al. 2005).

Following prior research, we define the reference point for each attribute as the average value of the attribute available in the market (Orhun 2009; Chen and Turut 2013; Rao and Turut 2013). The two attributes that we consider are: the level of quality and the price. When the firm does not introduce upgrades, period 1 consists of consumers who buy the base product or nothing. The reference price and reference quality are therefore $\frac{p_1}{2}$ and $\frac{1}{2}$ respectively[¶¶]. In period 2, the available quality levels remain the same but the

[¶¶]Note that market is not fully covered. In any period, the market consists of consumers who choose the outside option, i.e, not buying any product. Behavioral research has shown that choosing a higher-quality option such as buying a technological product signals consumers' technological skills and openness to new experiences (Thompson and Norton 2011). The presence of non-buyers is critical for buyers to experience relative social gain from using a high-quality product(Iyer and Soberman 2013). Without non-buyers, buyers price paid by the consumers is either 0 or p_2. Therefore, the reference price becomes $\frac{p_2}{2}$ as period 2 consists of consumers who buy the product at p_2 or who do not buy. Now consider the case when the firm introduces an upgrade in the second period. In this case, some consumers will choose to upgrade and experience a quality level of $1+w$. However, some consumers who previously bought will continue to use the old product and enjoy a product with quality 1. Finally , some consumers will not purchase the product in both periods. Thus, the reference quality in this case becomes $\frac{2+w}{3}$. There are alternative ways to formulate the reference point. For example, the reference point can be formed by past and future information (Lattin and Bucklin 1989; Kalyanaraman and Little 1994; Briesch et al. 1997; Kalyanaram and Winer 1995). In §3.6.2 we show that the qualitative nature of our results is robust to these alternative formulations.

We adopt the linear Loss Aversion Model (LAM) to model consumers' context-dependent preferences (Kivetz et al. 2004a; Kivetz et al. 2004b; Koszegi and Rabin 2006; Orhun 2009; Narasimhan and Turut 2013; Chen and Turut 2013; Rao and Turut 2013). In this model, consumers' total utility is the sum of the context-independent utility and the context-dependent utility. The utility of relative gains and the dis-utility of relative losses are additively separable. Kivetz et al. (2004b) has shown that this linear LAM model with a reference point defined as the centroid of the choice context can capture a wide variety of context effects, because the reference point is endogenous to the choice context and incor-

of a technological product cannot obtain such social gain. Similarly, without non-buyers or consumers who use older models, buyers of an updated product cannot experience the social gain. Therefore, the outside option needs to be incorporated into the reference point to capture the social comparison between buyers of the product and non-buyers.

porates information of all alternatives in the context. Let q^r denote the reference quality and p^r denote the reference price in a choice context. The relative utility of consuming a product of intrinsic quality q purchased at price p can be written as:

$$\begin{aligned} U^r(p,q;\theta,\gamma,\lambda) &= \theta\cdot(q-q^r)\cdot[\gamma\cdot\mathbb{1}(q\geq q^r)+\lambda\cdot\mathbb{1}(q<q^r)] \\ &- (p-p^r)\cdot[\lambda\cdot\mathbb{1}(p\geq p^r)+\gamma\cdot\mathbb{1}(p<p^r)] \end{aligned} \tag{3.2}$$

where γ and λ denote the gain and loss parameters, and $\mathbb{1}(\cdot)$ is a characteristic function that equals 1 if the expression in the function is true and 0 otherwise. For example, consuming a superior product $(q>q^r)$ at a premium price $(p>p^r)$ induces a gain on the quality dimension and a loss on the price dimension. The corresponding relative utility is

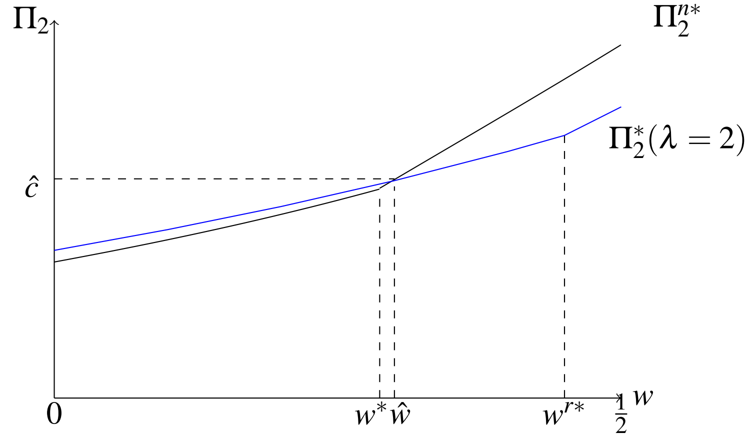
$$U^r(p,q;\theta,\gamma,\lambda)=\gamma\cdot\theta\cdot(q-q^r)-\lambda\cdot(p-p^r) \tag{3.3}$$

Losses loom larger than gains (Kahneman and Tversky, 1979; Kahneman et al. 1991; Tversky and Kahneman 1991). Hence $\lambda>\gamma$. To conserve notation, we set $\gamma=1$ and set $\lambda>1$ to model the idea that losses loom larger than gains. The consumer's total utility denoted by $U(p,q;\theta,\gamma,\lambda)$ is:

$$U(p,q;\theta,\gamma,\lambda)=U^c(p,q;\theta)+U^r(p,q;\theta,\gamma,\lambda) \tag{3.4}$$

Since the firm makes the upgrade decision at the beginning of period 2, the firm introduces an upgrade if selling it increases the period 2 profit. Under context-dependent preferences, consumers' preferences for the upgrade are influenced by the relative standing of products. Given that the upgraded product is the most advanced product in the choice context, the presence of the upgraded product diminishes the comparative value of the base

Figure 3.6: Period 2 Profit Varies with Context Dependence



product and imposes a larger psychological loss on consumers who do not buy any products as they forgo the enjoyment of consuming a higher (reference) quality. In this aspect, contextual comparison would seem to favor the upgraded product, and introducing an upgrade would therefore be more attractive if the firm serves consumers with context-dependent preferences. Our results show that this intuition is valid in some situations. However, under some conditions, context-dependent preferences lower the profits of selling upgrades and lead to a smaller range of situations for the firm to introduce upgrades. Proposition 14 summarizes this result.

Proposition 8 ***(Upgrade Introduction)*** *There exists a positive $\hat{c}$ such that if $c < \hat{c}$ then context-dependent preferences increase firm's incentive to introduce upgrades. If $c > \hat{c}$ then context-dependent preferences decrease firm's incentive to introduce upgrades.*

Proposition 7 shows that without context-dependent preferences, w needs to exceed a threshold (denoted by $\underline{w}$), i.e., $w > \underline{w}$, for introducing an upgrade to be profitable. Proposition 14 reveals that with context-dependent preferences, this threshold (denoted by $\underline{w}^r$) is lower if the cost for upgrade introduction is small and higher if the cost is large. In other words, incorporating consumers' context-dependent preferences results in a larger range of situations for the firm to introduce low-cost upgrades and a smaller range of situations for the firm to introduce high-cost upgrades (see Figure 3.6).

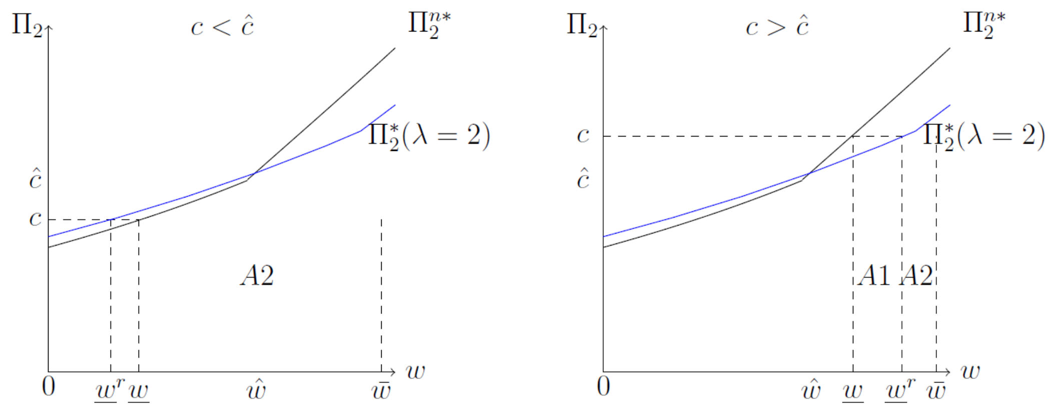
To understand this result, first note that under context-dependent preferences, the introduction of an upgrade has two counteracting effects that impact new and existing consumers differently. The first effect is a *reference quality effect*, namely when an upgraded product is added to consumers' context, the reference quality in the context shifts upward. As a result, consumers perceive a smaller gain for using the base product and a larger loss for not buying. This reference quality effect makes the upgraded product relatively more appealing. However, we also need to consider the reference effect on the price dimension. In making payments, consumers experience a psychological loss above and beyond the economic cost of the purchase. Consequently, consumers with context-dependent preferences are essentially more sensitive to prices. We refer to this effect as a *reference price effect*.

Consumers who do not buy the base product experience a loss on the quality dimension. This loss is intensified when the arrival of an upgrade increases the reference quality. Even though these consumers would incur a loss for paying prices if they were to buy the upgrade, the loss in price is small compared to the loss in quality if they chose not to buy the upgrade. Therefore, context-dependent preferences motivate consumers who did not buy the base product to purchase the upgrade. On the other hand, existing consumers with context-dependent preferences are less motivated to purchase the upgrade. Existing consumers own the base product. Even though the relative quality of the base product decreases when an upgrade arrives, quality of the base product is still in the gain domain. However, if existing consumers were to buy the upgrade, paying for the upgrade would lead to a loss, which outweighs the decrease in the relative value in using the base product. Therefore, existing consumers with context-dependent preferences are less willing to buy the upgrade.

As analyzed in the benchmark model, when w is small, the firm targets the upgrade to new consumers who do not own the base product. When w is large, the firm also sells the upgrade to existing consumers. Given the diverging impact of context-dependent preferences on new and existing consumers, the region of parameters for introducing low- and high-cost upgrades change in opposite directions. For example, when c is small and $w \in (\underline{w}^r, \underline{w})$ (see Figure 3.7 left), context-dependent preferences lead the firm to introduce the upgrade which otherwise would not be optimal in the absence of context-dependent preferences. Similarly, when c is large and $w \in (\underline{w}, \underline{w}^r)$ (see Figure 3.7 right), ignoring consumers' context-dependent preferences can lead the firm to introduce an upgrade that is unprofitable. This result states the importance of considering context-dependent preferences when they exist. Our findings show that context-dependent preferences encourage low-cost evolutional rather than high-cost revolutionary advancement in product design.

Our analysis so far has focused on the second period that is relevant for the firm's

Figure 3.7: Context-Dependent Preferences Increase Total Profits ($\lambda = 2$)



upgrade decision. Now we discuss how context-dependent preferences affect the firm's total profit in two periods. Context-dependent preferences increase the period 2 profit from selling low-cost upgrades. We could expect that the total profit from selling a base product followed by such upgrades would increase accordingly, which is indeed the case. On the other hand, context-dependent preferences decrease the period 2 profit of selling high-cost upgrades, driven by the negative reference price effect on existing consumers. Similarly, one may expect that the negative reference price effect also decreases the firm's profit from selling the base product in period 1. Consequently, the firm's total profit would be lower. Surprisingly, under some conditions, the firm can actually benefit from this negative impact of context-dependent preferences and obtain a higher total profit.

Proposition 9 ***(Total Profit)*** *As long as c is not too large and λ is not too small, there exists a region of w in which the monopolist's total profit is higher under context-dependent preferences.*

The range of parameters that satisfy the conditions in Proposition 15 is shown in Figure 3.7 (see Regions A1 and A2) where the degree of loss aversion takes a specific value ($\lambda = 2$). This region corresponds to the situations in which context-dependent preferences mitigate the firm's commitment problem with respect to introducing upgrades. In the beginning of period 2, the firm decides whether to introduce an upgrade with the objective of maximizing the profit in period 2 only. After consumers have purchased in period 1, in the beginning of period 2, the firm has an incentive to introduce an upgrade to boost profits in period 2. In anticipation of firm's incentives to introduce an upgrade, consumers withhold purchase in period 1, waiting for the upgrade. As a result, the profit in period 1 decreases. The firm would be better off if it could commit to not introducing upgrades in the second period, but the firm is tempted to introduce upgrades when $w > \underline{w}$, where $\underline{w}$ is the lower threshold for introducing upgrades to increases the period 2 profit. Such upgrade introductions are not profitable when $w < \min(\bar{w}, \frac{1}{2})$, where $\bar{w}$ is the lower threshold for introducing upgrades to increase total profits over two periods.

Context-dependent preferences can mitigate this upgrade commitment problem in two ways. First, as Proposition 1 shows, context-dependent preferences can decrease the profit of selling an upgrade. When this negative effect is sufficiently strong, it renders introducing upgrades unprofitable. As a result, the firm obtains profits from selling the base product over two period, which are higher than the profits from selling sequentially upgraded products. This case occurs when three conditions are satisfied: the cost of introducing upgrades exceeds the threshold given in Proposition 2 ($c > \hat{c}$); the level of quality improvement is such that the firm would only introduce the upgrade without context-dependent preferences ($w \in (\underline{w}, \underline{w}^r)$); λ is not too small ($\lambda > \underline{\lambda}$) (Region A1 in Figure 3.7). Context-dependent preferences can also mitigate the firm's upgrade commitment problem through directly improving the profit of selling upgrades. The total profit from selling the upgrade is higher if the firm sells the upgrade to new consumers only and the degree of loss aversion is not too small.

Let us illustrate this finding with a numerical example. Suppose that losses loom twice larger than gains, i.e., $\lambda = 2$. The corresponding $\hat{c} \doteq 0.05$ and $\hat{w} \doteq 0.30$ (see Figure 7). We first illustrate the first scenario discussed above (see Region A1). Suppose $c = 0.08 > \hat{c}$. At this cost, the minimal quality improvement required for introducing an upgrade with and without context-dependent preferences is $\underline{w}^r = 0.43$ and $\underline{w} = 0.36$ respectively. Suppose technological advances allow the firm to introduce an upgrade with 40% quality improvement over its base product, i.e., $w = 0.4$. Since $w \in (\underline{w}, \underline{w}^r)$, the firm would only introduce this upgrade if context-dependent preferences do not exist. In doing so, the firm obtains a profit of 0.11 in period 2 and a total profit of 0.36. If the firm considers context-dependent preferences, introducing an upgrade only generates a profit of 0.08 in period 2, less than 0.09 that it receives from selling the base product. Hence, the firm would sell the base product and the total profit would be 0.45, higher than 0.36. Now we illustrate the scenario in Region A2 (see Figure 3.7 left). Consider that $c = 0.02 < \hat{c}$. At this cost, $\underline{w} = 0.13$ and $\underline{w}^r = 0.09$. Suppose $w = 0.2$. Given that $w > \underline{w} > \underline{w}^r$, the firm introduces this upgrade in either case. Without context-dependent preferences, the firm's period 2 profit is 0.10 and total profit is 0.43. With context-dependent preferences, the firm's period 2 profit is 0.11 and total profit is 0.46, higher than 0.43. Clearly, the presence of context-dependent increases the firm's total profit.

Now let us examine the implication of context-dependent preferences on prices. Firms use inter-temporal price discrimination to extract surplus from consumers with heterogenous willingness to pay (Stokey 1979). In particular, a firm first sells a product at a high price to early adopters who have high willingness to pay, and then cuts price to sell the product to consumers whose willingness to pay is lower than the initial price. This strategy still applies for firms that introduce successive generations of products over time. It is unclear how consumers' context-dependent preferences affect a firm's inter-temporal price discrimination strategy. We answer this question in the following proposition.

Proposition 10 ***(Pricing)*** *Context-dependent preferences affect the firm's prices as follows:*

(a) *When the firm also sells the upgrade to existing consumers, both prices decrease.*

(b) *When the firm sells the upgrade to new consumers only, prices of the base product and the upgraded product can both increase.*

(c) *In cases (a) and (b), inter-temporal price dispersion increases.*

When the firm sells the upgrade to both new and existing consumers, prices of both products decline as a result of the reference price effect that we discussed earlier. In particular, when consumers experience a psychological cost in making payments, consumers become more sensitive to prices. The increased price sensitivity weakens the firm's ability to charge prices as high as that in the absence of the context-dependent preferences.

Therefore, equilibrium prices decline from the price levels without context-dependent preferences.

If the quality improvement is low so that the firm sells the upgrade to new consumers only, prices of the base product and the upgrade can both increase. The reason is that context-dependent preferences make purchasing the base product in period 1 more attractive as consumers who choose this option would only suffer a loss in paying for the price once. In doing so, the consumer enjoys a gain in consumption utility in both periods. Furthermore, the consumer experiences a gain in not paying for the upgrade in period 2. Compared to this option, consumers who wait to buy the upgrade would be hurt by loss aversion twice, when they forgo consuming the quality of the base product in period 1 and when they pay the price of the upgrade in period 2. Consequently, the willingness to pay for the base product is higher in the presence of context-dependent preferences. The firm can therefore charge higher prices in period 1, which also enables it to charge higher prices in period 2 as the two products are substitutes.

To understand the last part of the proposition, note that the price of the upgraded product is impacted more by the reference price effect. This can be seen from the following. The presence of context-dependent preferences, reflected by an increase in the loss aversion parameter λ, affects the period 2 price in the following way:

$$\frac{dp_2^*}{d\lambda} = \frac{\partial p_2^*}{\partial \lambda} + \frac{\partial p_2^*}{\partial p_1^*}\frac{\partial p_1^*}{\partial \lambda} \tag{3.5}$$

$\frac{\partial p_2^*}{\partial \lambda}$ represents the reduction in p_2^* directly driven by the reference price effect. $\frac{\partial p_2^*}{\partial p_1^*}\frac{\partial p_1^*}{\partial \lambda}$ is the further reduction in p_2^* indirectly driven by the reference price effect, through lowering the equilibrium price in period 1, which strategically shifts the equilibrium price in period 2 downward. These two effects together reduce the period 2 price by a larger degree than the price reduction in the period 1 price. Therefore, context-dependent preferences lead the firm to price discriminate more heavily over time.

Having examined the implication of context-dependent preferences on the firm, we discuss the implication of context-dependent preferences on consumer surplus and social welfare. We measure consumer surplus with the integrated total utility, summation of the context-independent utility and context-dependent utility, received by all consumers. From consumers' perspective, context-dependent preferences imply that consumer preferences for a product are influenced by its comparison to other alternatives in the choice context. Consumers derive relative utilities from comparative gains and losses which distort choice. Can context-dependent preferences lead to a higher consumer surplus, or does it always hurt consumers as a whole? The following proposition answers these questions.

Proposition 11 ***(Consumer Surplus)*** *There exists a $\hat{\lambda} > 1$ such that if $\lambda < \hat{\lambda}$, consumer surplus is higher under context-dependent preferences. Furthermore, when $c < \hat{c}$ or $c > \hat{c}$ but λ is in a subset of the region bounded by $\hat{\lambda}$, social welfare is also higher than in the absence of context-dependent preferences.*

The proposition shows that consumers' tendency to make choices based on contextual comparisons among alternatives does not necessarily harm consumers. In fact, this behavior can actually benefit consumers and increase consumer surplus. This can occur as long as consumers' loss aversion is not too severe.

Let us understand this result. When consumers derive utility from the comparative gains and losses relative to the reference point in the choice context, consumer surplus needs to reflect the context-dependent utility. First, we fix prices and the consumption pattern to be the same as in the absence of context-dependent preferences. This setting represents the case that $\lambda = 1$, which reduces to the same consumer and firm decisions as in the absence of context-dependent preferences. In this case, including the utility of comparative gains and losses leads to a net increase in consumer surplus (see the Technical Appendix for details). This result implies that as long as λ is close to 1, i.e., consumers are nearly loss neutral, consumer surplus is higher with context-dependent preferences.

As λ increases, consumer surplus with context-dependent preferences decreases. To see this, an increase in λ affects consumer surplus in counteracting ways. Consider the case that existing consumers also purchase the upgrade. On the positive side, a higher λ drives prices to decline as loss-averse consumers are more sensitive to prices. The reduction in prices increases consumer surplus. In addition, as λ increases, θ_1 decreases, i.e., more consumers who otherwise would have postponed consumption purchase the base product early and consume it over two periods. This shift in consumption also increases consumer surplus. On the negative side, a larger λ directly reduces consumer surplus as it amplifies the dis-utility of comparative losses. Furthermore, as we have seen in Proposition 14, an increase in λ leads fewer existing consumers to purchase the upgrade. This decrease in consumption of the upgrade drives consumer surplus to decline. These negative aspects dominate the positive aspects. Thus, consumer surplus is decreasing in λ. As long as λ

is not too large, consumer surplus under context-dependent preferences can be higher than that without context-dependent preferences.

In a subset of the region specified in Proposition 17, social welfare can also be higher under context-dependent preferences. This is because when the firm sells the upgrade to existing consumers, the firm's profit is lower with context-dependent preferences. To make up for the reduction in the firm's profit, λ needs to be even lower so that the increase in consumer surplus can offset the decrease in the firm's profit.

This finding has important implications for public policy makers. Research has shown that loss aversion can be reduced by means such as emotion regulation (Sokol-Hessner et al. 2012), thinking like a trader (Sokol-Hessner et al. 2009), or thinking in a foreign language (Keysar et al. 2012). Our results suggest that once we consider strategic responses by firms to context dependent preferences, these techniques can sometimes hurt consumers and society.

3.6 Extensions

In this section, we will relax assumptions made in the base model to examine the robustness of our results and seek new insights. In the base model, we assume that the firm sells the upgraded product to new and existing consumers at the same price. This assumption may not always hold. In §3.6.1, we consider the case when the firm offers a separate upgrade price for existing consumers to buy the upgrade. In the base model, we assume that the reference price and reference quality are the average level in the current choice context. One may argue that consumers' references could be formed in other ways. In §3.6.2, we test the robustness of our results to some alternate models of reference point formation.

3.6.1 Upgrade Pricing

Our base model assumes that the firm sells the upgraded product to new and existing consumers at an uniform price. We observe that firms sometimes offer a special pricing for existing consumers to upgrade to new products. Here we assess the firm's upgrade introduction when it offers the special upgrade pricing. Specifically, in period 2, if the firm chooses to introduce an upgrade, it sells the upgraded product to new consumers at p_n and to existing consumers at p_u.

Without context-dependent preferences, selling the product to existing consumers at a separate upgrade price is always preferred. This is because after consumers have made purchase, the firm can offer a low upgrade price to extract more surplus from these consumers. In equilibrium, the firm sets p_u low enough that all existing consumers purchase the upgrade. The resulting consumption pattern is shown in Figure 3.8. This profit is strictly higher than that from selling the upgrade to new consumers exclusively or selling the upgrade to new and existing consumers at the same price. However, with context-dependent preferences, there are situations in which the firm may find it profitable to abandon this upgrade pricing policy.

Proposition 12 ***(Upgrade Pricing)*** *With context-dependent preferences, when w is small and λ is sufficiently strong, selling upgrades to new consumers only strictly dominates*

Figure 3.8: Consumer Choice Pattern With An Upgrade Price

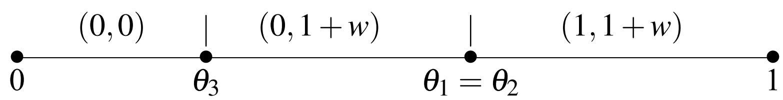
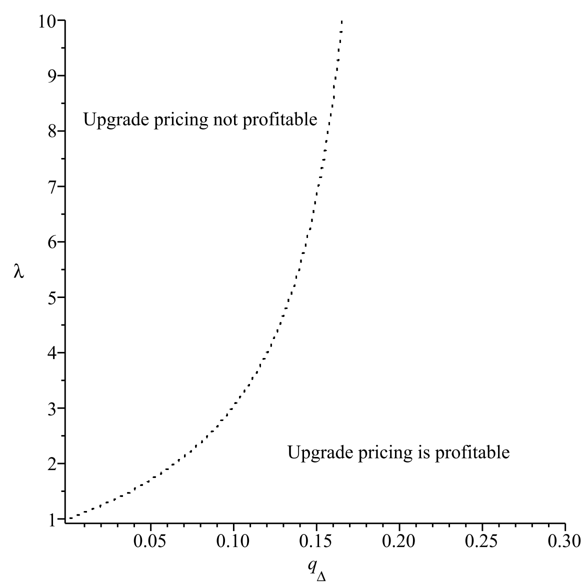


Figure 3.9: Upgrade Pricing with Context-Dependent Preferences



selling upgrades to both new and existing consumers with discriminating prices.

Figure 3.9 shows the region in which upgrade pricing is not profitable given the presence of context-dependent preferences. This intuition is that when the quality improvement is small, the upgrade price has to be reasonably low to attract existing consumers to purchase the upgrade. However, when consumers' loss aversion is strong enough, a low p_u reduces the reference price, imposing a larger loss for new consumers who buy the upgrade at p_n, which in turn decreases the profit of selling the upgrade. In this case, the firm would rather sell the upgrade to new consumers only. This finding adds new insights to existing research on a firm's upgrade policy. For example, Bala and Carr (2009) show that upgrade pricing can be an effective tool for selling upgrades to strategic consumers. Sankaranarayanan (2007) shows that offering existing consumers free upgrades can reduce the firm's profit from selling an upgrade, thereby alleviating the firm's upgrade commitment problem. However, such study did not incorporate the contextual effects associated with upgrade pricing. Our finding suggests that an especially low upgrade price lowers the reference price perceived by consumers, thereby penalizing new consumers who buy the upgrade at the high new-user price. As a result, offering special upgrade pricing can reduce the firm's profit.

Similar to the base model, at a given degree of loss aversion, the firm sells the upgrade to new consumers only when w is small and to both new and existing consumers when w is large. In the latter case, the profit from selling the upgrade is reduced by context-dependent preferences, consistent with the results in the base model.

3.6.2 Alternative Reference Formulations

In the base model, we defined the reference point as the average value in the current market. This parsimonious specification captures the essence of context-dependency effects. However, the intuition behind our results holds more broadly for alternative specifications of the reference point. To see this, note that the driving force of our main result is that context-dependent preferences affect new consumers and existing consumers differently. As new consumers do not own the base product, they are affected more by the reference quality effect which motivates them to buy the upgrade. In contrast, existing consumers could use the base product as an alternative to buying the upgrade at an extra cost. Therefore, the positive reference quality effect is dominated by the negative reference price effect, discouraging existing consumers from buying the upgrade. This aspect would hold in alternative formulations of reference point and therefore we expect the base nature of our results to hold. To verify the robustness of our results, we extended our model to consider three other assumptions of reference point formation: (1) reference point excludes the outside good; (2) reference point formed by past and future choices; (3) reference point formed by product offered in the past. We discuss the main results below and details can be found in the supplementary appendix.

Let us discuss the first alternative assumption. In the base model, the reference point is defined as the average among products used by all consumers in the current market, including consumers not using any products, i.e, choosing the outside good option. This formulation captures the fact that the presence of consumers not adopting a product drives the comparative social/psychological prestige experienced by adopters. In the extreme case that no consumers choose the outside good and all consumers buy the product, adopters would not experience comparative gains (Iyer and Soberman 2013). However, one may argue that reference point is shaped by alternatives in the product category and excludes the outside option of not buying any product. For example, in period 2, both the upgrade and the base product are available in the market. The reference quality is $\frac{2+w}{2}$. Users of the two products pay either p_2 for buying the upgrade or nothing for continue using the base product. Hence the reference price is $\frac{p_2}{2}$. Given that there is only one product in period 1, consumers who buy the product are not affected by context-dependent preferences. Our main results still hold under this assumption. When w is large such that existing consumers also purchase the upgrade, reference price effect drives period 2 prices to decline and reduce the profit of introducing upgrades. When w is small that only new consumers purchase upgrades, reference quality effect dominates and motivates new consumers to buy upgrade to enjoy a comparative gain in quality. Period 2 prices increase and introducing upgrades is more profitable accordingly.

The reference point in our base model is determined by contemporary contextual factors, i.e., composition of consumers using various products in the current period. Some research has shown that consumers' reference point may also be influenced by temporal factors such as choices available in the past as well as in future expectations (Winer 1986; Rajendran and Tellis 1994; Mazumdar et al. 2005). To incorporate the temporal information, we combine consumer choices made over the two periods to derive the overall reference point. In this way, four consumer choices can arise. They are denoted by $(1,1+w)$, $(1,1)$, $(0,1+w)$, and $(0,0)$ in Figure 3.2. The corresponding total quality provided by each choice is $2+w$, 2, $1+w$, and 0 respectively. The reference quality is $\frac{5+2w}{4}$. Similarly, the total price commanded by each of the four choices is p_1+p_2, p_1, p_2, and 0. Hence, the reference price is $\frac{p_1+p_2}{2}$. In this case, existing consumers who purchase early experience a gain in consuming the above-reference quality and a loss in paying the above-reference prices. New consumers who wait experience a loss in quality and a gain in saving money. As in the base model, the firm's profit from selling low-cost upgrades to new consumers increases whereas the profit of selling high-cost upgrades to existing consumers decreases. Thus, the basic intuition of our model continues to hold even in this case.

Research shows that reference point is likely formed by the observed product offering in the recent past (Winer 1986). In the context of our model, the firm offers the base product to be used over two periods for a price of p_1, which sets the reference quality of 2 and reference price of p_1. For new consumers, buying the upgrade in period 2 is associated with a loss $2-(1+w)=1-w$ on the quality dimension and a gain p_1-p_2 on the price dimension, whereas not buying would result in a loss 2 in quality and a gain p_1 in price. The loss in quality looms larger, motivating new consumers to buy the upgrade. Existing consumers could either buy the upgrade to receive a gain w in quality and a loss of paying extra p_2 in price. Alternatively, they could choose the reference option by buying the base product to use over two periods. Profits of selling upgrades to existing consumers decrease with context-dependent preferences. Therefore, consistent with the base model, context-dependent preferences motivate the firm to introduce small upgrades which targets new customers and discourage the firm to introduce major upgrades that also attract existing consumers.

Lastly, it is important to note that the results are driven by the combined impact of reference price and reference quality, rather than by any one of them alone. Specifically, reference price effect makes consumers more price sensitive, reducing the firm's profit of selling upgrades. Reference quality effect motivates consumers to buy high quality product to enjoy the comparative gain from consuming high quality product, which therefore increasing firm's profit of selling upgrades. However, the overall impact of the two effects differ for new and existing consumers. This is the driving force of our results.

3.6.3 w is Endogenous

Thus far, we have assumed that w, quality improvement in the upgrade, is exogenously determined by technology advancement. Now we relax this assumption and allow the firm to endogenously invest in R&D to increase w. Let $R(w) = \frac{kw^2}{2}$ denote the R&D investment required for improving quality of the product by w. Suppose the firm can choose to increase the quality of the base product by 0%, 20%, or 40%, i.e., $w \in \{0, 0.2, 0.4\}$, where $w = 0$ indicates not investing in R&D. Note that this R&D decision is made in the beginning of period 2, hence, the firm in period 1 cannot make a credible commitment about the level of w. Suppose $k = 1$, i.e., $R(w) = \frac{w^2}{2}$, without context-dependent preferences, the firm would be better off choosing $w^* = 0.4$, as it yields the highest profit in period 2 (see the Technical Appendix for details). However, with context-dependent preferences, suppose consumers' loss aversion parameter is $\lambda = 1.2$ or higher, the firm would prefer to introduce smaller upgrades as $w^* = 0.2$. This simple example illustrates that context-dependent preferences lead firms to introduce smaller upgrades.

3.6.4 Technology for Introducing Upgrade is Available in Period 1

In our main model, we focused on situations in which technology for producing the upgrade is not available in period 1 and therefore the firm can only introduce successive generations of improved products over time. We showed that context-dependent preferences can alter firm's upgrade introduction strategy and improve firm's profits. Although many high-technology products such as computers, telecommunication devices, and electronics heavily depend on new technology to improve product quality and fall into our considered context, it may also be interesting to explore the impact of context-dependency effect on firm's profits when technology for introducing the upgrade is available in period 1. Specifically, consider that firm can introduce two versions of the product in period 1. Consumers with heterogenous valuations for quality are either in segment h or l who value product with quality q at $\theta_h q$ and $\theta_l q$ respectively and $\theta_h > \theta_l > 0$. The size of the h segment is α and the size of the l segment is $1 - \alpha$. The marginal cost for the firm to supply a product of quality q is $\frac{q^2}{2}$. The firm makes a product line decision by setting the quality and price of the high and low-end products.

Without context-dependent preferences, this problem is a classic one and has been studied by researchers (see Moorthy and Png 1992 for detailed analysis). When firm simultaneously introduces two products, the low-quality product would cannibalize demand for the high-quality product. To discourage high-valuation consumers to purchase the low-quality product, the firm can lower the quality of the low-end product. Now we incorporate context-dependent preferences into the analysis and verify if context-dependent preferences can still benefit the firm. Our findings are summarized in the following proposition.

Proposition 13 *When firm introduces two products in period 1, if $\lambda < \frac{\theta_h}{\theta_l}$, i.e, consumers are not too loss averse, context-dependent preferences increase firm's profits. Furthermore, quality of the high-end product increases and quality of the low-end product decreases. If $\frac{\theta_h}{\theta_l} \geq 2$, then prices of both products increase.*

Detailed analysis are included in the Technical Appendix. The intuition for the result is as follows. When consumers exhibit context-dependent preferences, choosing the high-end product induces a gain in quality and a loss in price. Conversely, choosing the low-end product induces a loss in quality and a gain in price. As high-type consumers value quality more than low-type consumers, high-type consumers are therefore more sensitive to the gain and loss on the quality dimension, which discourages high-type consumers to choose the low-end product and reduces cannibalization between two products. As a result, firm's profits by offering two products can increase with context-dependent preferences.

3.6.5 Multiple Time Periods

We model the implication of context-dependent preferences on firm's upgrade introduction strategy with a two-period model, consistent with existing literature on durable-good monopolist (Bulow 1982; Dhebar 1994; Desai and Purohit 1998; Kornish 2001; Desai et al. 2004). Although we believe this setup is sufficient to reveal the durable nature of the product and capture the dynamic implications of context-dependent preferences on firm, it is helpful to verify the robustness of context-dependency effect over more than two time periods. Consider a formulation with T time periods where $T > 2$, in each period $t > 1$, the firm can incur a cost c_t to introduce an upgraded product with incremental quality $w_t \in (0, \frac{1}{2})$ and sell it for price p_t. Each product is good to consume for two periods. In period t, the reference quality q_t^r is the average level of quality consumed by consumers in period t and the reference price p_t^r is the average price consumers pay in period t. Other settings in the main model apply.

At the beginning of the last period, i.e, $t = T$, the firm faces consumers who own the previous model of the product with quality $1 + \sum_{t=2}^{T-1} w_t$. These consumers can continue using the previous model in the last period. The firm also faces consumers who do not own an older model that can be used in the last period. These consumers either purchased the model in period $T-2$ which expires in period T or did not use any product in period $T-1$. These consumers are analogous to the new consumers in the main model. The upgrade's quality is $1 + \sum_{t=2}^{T} w_t$ and price is p_T. Hence the last period consists of consumers using the latest model, the previous model, and nothing. The reference quality is $\frac{q_T + q_{T-1}}{3} = \frac{2q_T + w_T}{3}$. Consumers in the last period either pay p_T for the upgraded model or nothing. The reference price is $\frac{p_T}{2}$. As in the main model, existing consumers can still experience a gain in quality by consuming the previous model in the last period, whereas replacing the previous model with an upgrade induces a loss in price. Consumers who do not have a previous model to consume in the last period experience a comparative loss in quality if they do not buy the upgrade in the last period. This comparative loss outweigh the loss in paying the price for the upgrade. Therefore, context-dependent preferences motivate new consumers to buy upgrades while dissuading existing consumers to do so. As a result, firm's incentive to introduce small upgrades that target new consumers increases and firm's incentive to introduce major upgrades that attract existing consumers decreases. For any period $t \in [2, T-1]$, the market comprises of consumers who use the latest upgrade, the earlier product, or nothing, and consumers either pay p_t for the upgrade or nothing, as in the last period. The marginal consumer in the first period chooses to buy the current model for use over two periods or to wait for the upgraded product in the next period, as in the first period of the base model. Therefore, we believe this decision is impacted by context-dependent preferences in a similar fashion as in the base model. When context-dependent preferences lead to unprofitable future upgrades, firms gain more profits ex ante by introducing fewer upgrades.

3.7 Conclusion

In this paper, we investigated a monopolist's optimal upgrade strategy when consumers exhibit context-dependent preferences. We developed a two-period game theoretical model, in which the firm decides whether to introduce an upgraded product in the second period. Our main findings are summarized as follows.

1. *How does the firm's optimal upgrade strategy change when consumers exhibit context-dependent preferences?* Context-dependent preferences lead to a larger

range of situations for introducing low-cost upgrades and a smaller range of situations for introducing high-cost upgrades. Therefore, in response to consumers' context-dependent preferences, the firm should introduce low-cost upgrades more aggressively and high-cost upgrades more conservatively.

2. *Can the firm benefit from consumers' context-dependent preferences?* Our results show that context-dependent preferences can directly improve a firm's total profit from selling sequentially upgraded products. Even when context-dependent preferences reduce the firm's profits from selling upgrades, this negative impact can still benefit the firm by mitigating its upgrade commitment problem.

3. *Can consumers benefit from their context-dependent preferences?* As long as consumers' loss aversion is not too severe, consumer surplus and social welfare can both increase with context-dependent preferences.

4. *How do context-dependent preferences impact a firm's upgrade pricing policy?* Without context-dependent preferences, selling the upgrade to existing consumers at a separate upgrade price is always preferred. However, considering context-dependent preferences, the firm should abandon this pricing policy when the quality improvement in an upgrade is small and consumers are sufficiently loss averse.

There are several promising directions for future research. First, in order to focus on the firm's upgrade introduction decision, we treated the firm's R&D level as given by assuming that the magnitude and cost of upgrade improvement are exogenous. In general, we would expect that the costs of R&D and the magnitude of product improvement would be related. In this case, our results suggest that context-dependence would lead to more low-cost incremental innovations. Future research can further examine situations in which firm's R&D decisions are endogenous. In this paper, we have studied the impact of context dependence on the decisions of a monopolist. It would be interesting to examine how the optimal upgrade strategy under context-dependent preferences would change with competition. Our theoretical model reveals that context-dependent preferences change the willingness to buy upgrades by new and existing consumers differently. It would be interesting to empirically explore the impact of context-dependent preferences on consumers, and how such preferences impact firm profits.

4 SAME OR DIFFERENT? A PRODUCT DESIGN QUESTION

4.1 Introduction

Conspicuous consumption of luxury goods such as cars, handbags, and watches provides social prestige (Belk 1988, Veblen 1989, Bagwell and Bernheim 1996). According to a recent industry study, the overall global expenditure on luxury goods exceeded $1.1 trillion in 2014 (Bain 2014, Wahba 2014). In the United States, spending on luxury cars amounted to $438 billion and spending on personal luxury items, including clothing and accessories, was estimated to be $81 billion (McCarthy 2015). LVMH (Louis Vuitton Moet Hennessy), the most valuable luxury brand in the world, was estimated to have a brand value of about $26 billion. The LVMH Group's total revenue for the 2013 fiscal year was about $34 billion (Statista 2015). With a healthy growth of 7% from 2013, the luxury goods industry is becoming an increasingly important economic sector.

Brands selling luxury goods often carry high-end premium products sold at higher prices and low-end products that are more affordable. The central question that we ask in this paper is whether high-end and low-end products should look the same or different. In other words, should brands unify or diversify the exterior design of their high-end and low-end products?

Observations suggest that brands have made different choices on this exterior design decision. Some brands have chosen design unification. For example, the German luxury automaker, Audi, has long been known for its "Russian doll" design strategy. Its $70,000

A8 model looks more or less the same as its $30,000 A4 model (see Figure 4.1). In fashion industry, Hermès' six-figure Birkin bag looks very similar to its less expensive Kelly bag (Groer 2006, Bureau 2012). Louis Vuitton, Coach, and Michael Kors carry a wide price range of handbags with the same color and logo design (TFL 2013). In contrast, other brands have chosen design diversification. For example, Mercedes introduces more variations in the design of its products. Its high-end S-Class looks very different from its low-end C-Class (also see Figure 4.1). Burberry sells its classic trench coats with prices ranging from $750 to $7,500 with distinctive color schemes: Low-end coats are in neutral colors, such as black and brown, while high-end coats are in bold colors, such as purple and green. Similarly, when Apple introduced two lines of iPhones in 2013, Apple also used different color schemes to differentiate the look of its high-end phones and low-end phones: the high-end iPhone 5s, priced at $199 (with contract), was available in neutral colors including space grey, gold, and silver, while the low-end iPhone 5c priced at $99 (with contract), was in distinctive bright colors including pink, blue, yellow, and green.

These observations of business practices do not offer an obvious answer to the product design questions: Should brands design high-end and low-end products to look the same or different? It is puzzling why brands choose different design strategies. It is unclear which design strategy is optimal and under what conditions brands should choose one over the other. The existing research on exterior design of products is scarce. There is little guidance to practitioners on how to make this exterior design decision.

The objective of this paper is to fill this research gap by examining brands' exterior

Figure 4.1: Low-end and High-end Car Models of Audi and Mercedes-Benz

These are pictures of 2010 car models from thecarconnection.com.

design differentiation strategy. Specifically, we address the following research questions: (1) What is the optimal exterior design differentiation strategy? Under what conditions should brands unify design, and under what conditions should brands diversify design? Moreover, the exterior design decision is made in the early stage of a product's development process. It is important that we understand the implications of exterior design decisions on other marketing decisions such as functionalities and prices that are made afterward. Specifically, we ask the following research questions: (2) How should brands set prices of high-end and low-end products based on their design differentiation strategy? (3) How should brands set functionalities of high-end and low-end products based on their design differentiation strategy? In addressing these questions, we also provide one possible explanation to the puzzling dichotomy in brands' design choices that are observed among brands in different industries as well as brands in the same industry and face similar market conditions. Specifically, we answer the questions: (4) Why do some brands use the same design while other brands use different designs for high-end and low-end products? Can it be optimal for competing brands to choose different design differentiation strategies? Can the criticized "Russian doll" design unification be a profitable design strategy?

These research questions are important for the following reasons: From marketing researchers' perspectives, the substantive area of the exterior design of products has not been fully investigated. It is important that we as marketing researchers understand how exterior product design, in general, and exterior design differentiation between high-end and low-end products, in particular, influence consumer preferences and choices as well as brand profits. From managers' perspectives, exterior product design is important for products in a wide range of industries where consumption is conspicuous and provides social value. Designing a product is a costly investment that has long-lasting impact on the success of the product. Therefore, managers need to carefully choose the optimal exterior design strategy for their brand.

In order to address these questions, we first attempt to understand the implications of a brand's design differentiation strategy on consumer preferences for the brand's high-end and low-end products. Such knowledge will help us analyze the optimal design strategies that brands should choose, anticipating its impact on consumer preferences and sales. For this purpose, we use cars as an example of a status good. We empirically examine the impact of design differentiation of cars on consumers' preferences for cars. We compile a comprehensive dataset that comprises of 207 car models owned by 32 brands sold in the U.S. market from 2001 to 2010. We analyze pictures of all cars with image-processing software, and quantify the design differentiation of each car model within each brand. We infer consumer preferences for cars by modeling consumers' car choices using a random-coefficient logit model. Our empirical analysis shows that consumers prefer high-end cars to look more differentiated but prefer low-end cars to look less differentiated. This finding suggests that if a brand chooses to diversify design, i.e., increase the design differentiation of high-end and low-end products, it will increase the utility of the brand's high-end products but decrease the utility of the brand's low-end products. This result is intuitively consistent with behavioral research that shows that high-end consumers prefer to differentiate from low-end consumers while low-end consumers prefer to assimilate with high-end consumers (Brewer 1991, Fromkin and Snyder 1980). However, the opposing preferences for design differentiation presents brands a product design dilemma - should a brand unify design to improve the appeal of its low-end products or diversify design to improve the appeal of its high-end products?

To answer this question, we build a game-theoretic model to examine competing brands' incentives to unify or to diversify design. Based on the empirical finding, we specify that design diversification within a brand increases the utility of the brand's high-end product but decreases the utility of the brand's low-end product. In the words, we assume that consumers purchasing a high-end product prefers design diversification so that the high-end product looks differentiated from its low-end counterpart. On the other hand, consumers purchasing a low-end product prefers design unification so that the low-end product looks similar to its high-end counterpart. We analyze consumer choices given prices, functionalities, and exterior design of products. We further examine brands' optimal exterior design strategy, pricing, and product functionality decisions.

Several interesting findings emerge from the analysis. First, we find that when high-end consumers strongly prefer design diversification and low-end consumers strongly prefer design unification, the opposing preferences can pull symmetric brands to choose asymmetric design strategies i.e., one brand unifies design and another brand diversifies design. Furthermore, the asymmetric design strategies can be a win-win outcome. It is a win-win outcome in the sense that, by adopting different design strategies, both brands make higher profits than if they chose the same design strategy. This result provides a rationale for the dichotomous design choices that brands make, even when they are in the same industry and face similar market conditions. The general intuition behind this result is the following: By adopting different design strategies, brands avoid head-to-head competition in two markets. Instead, each brand establishes a comparative advantage in a different market and makes higher profits. Specifically, the brand that unifies design has a comparative advantage in the low-end market, whereas the brand that diversifies design has a comparative advantage in the high-end market. Each brand can sell its advantageous product at a higher price, obtains a higher market share in the advantageous market, and makes higher profits. This win-win situation can arise as long as the overall market conditions of the high-end and low-end markets — in terms of market size, intensity of competition, and product differentiation in functionality — are not too different. Moreover, adopting different design strategies is more profitable when competition between brands is more intense and competing products are less differentiated in functionality. In these cases, competing brands have more incentives to avoid competition by choosing different design strategies.

Second, our analysis shows that when high-end consumers have strong preferences for design diversification while low-end consumers have weak preferences for design unification, brands face a prisoner's dilemma: Each brand has incentives to diversify design. However, when both brands diversify design, the benefit of costly diversification cancels out. Brands would have been better off if they could both commit to design unification.

Third, our analysis shows that when brands choose different design strategies, brands should adjust prices of products based on their design strategy. Specifically, the brand that diversifies design should raise prices of its high-end product and decrease prices of its low-end product, because diversification in design strengthens the appeal of its high-end product but weakens the appeal of its low-end product. In contrast, the brand that unifies design should reduce prices of its high-end product and increase prices of its low-end product, as unification influences the appeal of products in the opposite direction.

Fourth, we also show that brands adopting different design strategies should further adjust the functionalities of their products in response to their exterior design strategy. Specifically, the brand that diversifies design should produce a high-end product that has more mainstream functionalities and a low-end product that has more niche functionalities. This is because, as more high-end consumers purchase from the brand that diversifies design, the heterogeneity in consumer taste for functionality increases. The new set of diverse consumers can be better served with a more mainstream product. In the meantime, fewer consumers purchase from the brand that diversifies design and the consumers who stay have a similar niche taste. The brand can cater to these consumers better with a product that has more niche functionalities tailored to their taste. By the same logic, the brand that unifies design should produce a more mainstream low-end product and a more niche high-end product.

Lastly, we consider competing brands that choose design strategies sequentially. We find that the sequential order of design decisions does not change the equilibrium design strategies. Furthermore, we show conditions where a first mover has incentives to choose design unification over diversification. Hence, the seemingly unattractive Russian doll design unification can be a profitable choice for not only brands that simultaneously choose design but also a brand that can choose design before the competitor does. We extend the main model in several dimensions to show the robustness of our results and present new insights.

4.1.1 Literature Review

This paper adds to the growing stream of marketing research that incorporates consumers' psychological and social behavior in quantitative models to examine optimal firm decisions. This stream of research enriches traditional economic models with psychological realism and provides new insights. Within this broad area, this paper is closely related to studies on conspicuous consumption of status goods. When consumers choose a status good, the decision is influenced by not only the intrinsic value of the good but also social considerations from consuming the good. In a reference group framework with two segments of consumers, i.e., snobs and followers who desire exclusivity and conformity, respectively, Amaldoss and Jain (2005a, 2005b) examine optimal pricing decisions and show that the demand curve of snobs can be upward-sloping in the presence of followers. Amaldoss and Jain (2008, 2010) examine product decisions and show that reference group effects can induce product proliferation and motivate firms to offer limited editions. Amaldoss and Jain (2015) further show that when brands adopt symmetric branding decisions, umbrella branding can soften competition and improve profits in situations where it decreases profits in a monopoly. Our paper differs from the above studies by examining the exterior design differentiation between high-end and low-end products, a substantively important decision that has not been studied before. In addition, our analysis reveals a new mechanism that softens competition, which happens when brands adopt asymmetric design strategies. Kuksov and Xie (2012) show that a status-good manufacturer can benefit from a competitor's cost reduction and entry of a competitor. Yoganarasimhan (2012) investigates firms' information provision and shows that a firm selling status goods can choose to either cloak or flaunt information to alter the level of social interactions. Rao and Schaefer (2014) study a status-good firm's dynamic pricing decision. They find that consumers' status concerns lead a monopolist to cut prices of durable goods more sharply over time. We augment this stream of literature by investigating exterior design differentiation between high-end and low-end products of brands selling status goods. We also investigate the implications of exterior design on pricing and functionality choices of products.

This paper is also related to the literature on product differentiation. Prior research has studied vertical product differentiation (Mussa and Rosen 1978, Gabszewicz and Thisse 1979, Shaken and Sutton 1982, Moorthy 1988) and horizontal product differentiation (Hotelling 1929, d'Aspremont et al. 1979). Researchers have also studied product differentiation in multiple attributes (Vandenbosch and Weinberg 1995, Ansari et al. 1998, Irmen and Thisse 1998) or in (uniform and customized) pricing policy (Guo and Zhang 2015). There have been limited studies that analyze product differentiation in the exterior design differentiation strategy where the exterior design differentiation between high-end and low-end products influences the status value of these products. We show that by choosing different exterior design strategies, i.e., one unifies design and one diversifies design, brands can differentiate from each other in the status value of their products, soften competition, and achieve a win-win outcome.

Lastly, this paper is broadly related to the limited marketing research that studies the visual aspects of products and marketing activities. Wedel and Pieters (2000, 2004) study the visual characteristics of advertisements on consumers' memory of brands and attention to advertisements). Landwehr et al. (2011, 2013) study the visual design aspects of cars. They show that prototypical and complex designs are fluent to process and positively impact sales. However, as exposure to design increases, consumers may like atypical design more. Liu et al. (2015) show that the prototypicality of design has an inverted-U shaped impact on consumer choices, and moderates the effects of marketing activities on sales. Different from these studies, we explore the impact of the visual design differentiation between high-end and low-end products of a brand on consumer preferences for the brand's high-end and low-end products. Moreover, build on the empirical finding, we focus on examining brands' optimal design differentiation strategies using a game-theoretic model. We give the market conditions in which brands should unify or diversify design, and explain why brands in the same market condition choose different design strategies.

The rest of the paper is organized as follows: In §4.2, we empirically examine the impact of a brand's design differentiation strategy on consumer preferences for the brand's high-end and low-end products. Based on the finding, we examine how brands should make the design differentiation strategy. In §4.3, we present the main game-theoretic model, analyze equilibrium strategies, and discuss results. In §4.4, we relax several assumptions made in the main model to show robustness of results and seek new insights. In §4.5, we conclude with managerial implications and avenues for future research.

4.2 Consumer Preferences for Design Differentiation

In order to examine brands' optimal design differentiation strategy, we start by examining the impact of a brand's design differentiation strategy on consumers' preferences for the brand's high-end products and low-end products. Specifically, we answer the following questions: If a brand diversifies design such that high-end and low-end products look more differentiated or distinctive, do consumers' preferences for the brand's high-end products and low-end products increase or decrease? We expect that a brand's design differentiation strategy has an important impact on consumer's satisfaction from consuming the high-end and low-end products. Taking Audi as an example, a consequence of its design unification is that consumers who spend \$70,000 on an A8 may be mistakenly recognized as driving a \$30,000 A4, which is not very pleasing (Ramsey 2012, Martin 2012, Roux 2013). On the other hand, it may be appealing for consumers who spend \$30,000 on an A4 to appear as if they drive a \$70,000 A8. In contrast, design diversification between high-end and low-end products can meet the needs of high-end consumers who prefer design to be distinctive, so that design can clearly highlight their costly purchase that others cannot afford. However, it may come at the cost of reducing the appeal of the brand's low-end product. For example, the colorful iPhone 5c that looks different from the high-end iPhone 5c has been criticized as lacking a premium look and feel (Beavis 2014, Bhasin 2013). The opposing preferences for design diversification and unification by high-end and low-end consumers are consistent with the notion that high-end consumers desire uniqueness and separation from low-end consumers, while low-end consumers desire similarity and association with high-end consumers (Brewer 1991, Fromkin and Snyder 1980). Hence, our hypothesize that:

> **H_1:** *Design differentiation within a brand increases consumer preferences for the brand's high-end products but decreases consumer preferences for the brand's low-end products.*

We use secondary data from the automobile industry to test this hypothesis. The automobile industry is an ideal empirical context to study the exterior design differentiation between high-end and low-end products for the following reasons: First, car brands carry a range of high-end and low-end car models that serve different social and demographic consumer segments. Second, cars are conspicuously consumed status goods. This allows the exterior design of cars to play an important role in influencing the social utility that consumers derive from high-end and low-end cars. We describe the data, model, and results separately below.

4.2.1 Data

Market Share. We collect monthly sales of 207 passenger car models (e.g., BMW 1-series) that are associated with 32 brands (e.g., BMW) and sold in the U.S. market between 2001 and 2010 from the Automotive News market data books. We calculate the market size in month t as $M_t = \frac{I_t \cdot C_t}{12 \cdot A}$ (see the same approach used in Sudhir 2001, Balachander et al. 2009, Liu and Shankar 2015). The number of households (I_t) in month t is collected from the Statistical Abstract of the United States, C_t is the average number of cars per household in month t collected from Simmons database, and A is the average age of cars that is 10.70 years according to Ward's Automotive Yearbooks. Based on monthly market size and sales of car models, we derive monthly market share of car models and the market share of the outside good, i.e., the option of not buying any car models.

Exterior Design. The focal independent variable is the exterior design differentiation of cars within each brand. To construct this design variable, we first collect exterior design characteristics of all car models in the dataset. To do so, we download pictures of cars from Edmunds.com, a car-buying resources website. Edmunds provides standard 360 degree views of the exterior design of cars, which allows us to obtain the frontal, side, and back images of all cars. Design studies show that the frontal design of cars is the most

Figure 4.2: Illustration of Design Attribute Points

important aspect for car recognition (Ranscombe et al. 2012). Hence, we collect car design characteristics from the frontal image of cars. We use image-processing software to analyze the frontal pictures of cars. First, we normalize the size of each car by shrinking the car picture so that the width of a car is unity (without changing the relative height-to-width ratio of that car). Second, we define the center of a car's base to be the origin of a two-dimensional space, and lay each car picture in that two-dimensional space. Third, from each car picture, we extract the locations of 50 design attribute points including grill, headlights, bumper, mirrors, windshield, and the body shape of the car (see Figure 4.2 for locations of the 50 attribute points and Landwehr et al. 2011, 2013 for this approach). The location of each attribute point is represented by a vector of (x, y) coordinate values in the two-dimensional space.

For any two cars, with the coordinate values of their design attribute points, we can quantify and measure the degree of design differentiation between the two cars. To do so, for each attribute point, we first compute the Euclidian distance between the location of the attribute point in one car and the location of the same attribute point in the other car. Then we sum the Euclidian distance across all 50 attribute points to derive a measure of the overall design differentiation. Imagine that each brand sells only two car models — a more expensive high-end car and a less expensive low-end car. Each car's design is characterized by (x, y) coordinates of $m = 1, .., 50$ attribute points. The design differentiation, d_{hl}, between the high-end (h) and the low-end (l) cars can be measured by the formula below:

$$d_{hl} = \sum_{m=1}^{50} \sqrt{(x_{hm} - x_{lm})^2 + (y_{hm} - y_{lm})^2} \tag{4.1}$$

However, most car brands carry more than two car models, which brings two complications. First, for a brand that carries more than two car models, it is clear that the most expensive car is the high-end product and the least expensive car is the low-end product. However, for cars in the middle, their type as to whether it is a high-end or a low-end car is less clear. To define the type of these cars, we compare their prices with the average price in their brand. If a car's price is higher (lower) than the average price in its brand, we categorize it to be a high-end (low-end) car. Second, when brands carry more than two car models, the formula in (4.1) that computes the design differentiation between the most expensive car and the least expensive car of the brand is inapplicable to measure the design differentiation of cars in the middle of the brand's price range. To account for cars in the middle, we need to operationalize the design differentiation construct in a way that it can capture the design differentiation of any cars of a brand. The thought process in developing such design variable is as follows: When a brand carries only a high-end car model and a low-end car model, the design differentiation between them reflects the distinctiveness of each car model relative to the other car model. Conceptually, it also reflects the distinctiveness of each car model relative to the average design in its brand. We can derive the average design in each brand by averaging the coordinate values for each attribute point across all car models of the brand. We operationalize the design distinctiveness of a car model in its brand by computing the design difference between the car model's design and the average design in its brand using Equation (4.1). This variable captures the design distinctiveness of any car model including those that are in the middle price range. A higher value represents that a car model carries a more distinctive design relative to the average design of its brand. As a result, it is easier to differentiate the car from the other cars of the brand based on design and to recognize it as a high-end or a low-end car. A lower value represents that the car model carries a more similar design to the average design of its brand and it is less likely that one can differentiate the car model from the other cars of its brand to recognize it as a high-end or a low-end car.*

Control Variables. We control for the impact of prices, advertising, and functional attributes of car models on consumer preferences and car choices. Prices are measured by deducting monthly cash rebates issued by manufacturers and dealers from annual manufacturer-suggested retail list price (MSRP), both collected from the Automotive News. Monthly advertising expenditure data are collected from the Ad$pender database.

* We use an online survey study to verify whether this objective measure of design differentiation captures the perceived design differentiation by consumers. 120 Mturk participants were recruited to rate on a five-point scale (1=Not Much, 5 = Very Much) how much a car model looks like car models of its brand. Results show that participants' subjective ratings of design differentiation are significantly and positively correlated with the objective measure of design differentiation ($R = -0.43$, $p < 0.001$). Please refer to the Appendix for detailed stimulus and description.

We operationalize prices and advertising variables by taking natural logarithm of prices and advertising expenditure. We collect functional attributes data from Ward's Automotive Yearbook and include horsepower, miles per gallon, car type (i.e. regular or sporty/specialty) and weight. We use horsepower-to-weight ratio of a car model as a measure of the car model's power (Berry et al. 1995, Sudhir 2001). We also collect car size data from cars.com. Car safety ratings are provided on a 4-point scale (i.e., good, acceptable, marginal, and poor) by the Insurance Institute for Highway Safety, and the predicted reliability ratings are provided on a 5-point scale by Consumer Reports. Table 4.1 summarizes the descriptive statistics of all variables.

Table 4.1: Descriptive Statistics

Variables (*notation*)	N	Mean	Std Dev	Min	Max
Sales (*sal*)	16,268	4,388	6,375	0	75,537
Market Share % (*shr*)	16,268	0.35	0.51	0	6.51
DV* (*y*)	16,268	-6.42	2.76	-15.89	-0.82
Design Differentiation (*dd*)	16,268	1.56	0.73	0.47	5.30
High End (*hig*)	16,268	0.44	0.50	0	1
Horsepower (*hp*)	16,268	6.65	2.22	3.45	41.43
Miles Per Gallon (*mpg*)	16,268	22.45	7.10	12.65	64.15
Size (*siz*)	16,268	1.31	0.15	0.48	1.71
Reliability (*rel*)	16,268	3.20	1.12	1	5
Safety (*saf*)	16,268	3.62	0.48	1	4
Regular (*reg*)	16,268	0.73	0.43	0	1
Coupe (*cou*)	16,268	0.37	0.48	0	1
Price k$ (*pri*)	16,268	26,705	17,410	5,357	121,347
Advertising million$ (*ads*)	16,268	10,583	11,037	0	92,190

*DV (Dependent Variable) is defined as $y_{jt} = ln(s_{jt}) - ln(s_{0t})$.

4.2.2 A Random-Coefficient Aggregate Logit Model

We build an aggregate random-coefficient logit model of consumers' car choices. Specifically, there are $t = 1, ..., T$ time periods. In period t, there are $j = 0, 1, ..., J_t$ car models available for purchase, where $j = 0$ is the outside good, i.e., consumers may decide not to purchase any car models. Each consumer $i \in \{1, , ..., N_t\}$ chooses a car model $j \in \{0, 1, , ..., J_t\}$ in period $t \in \{1, , ..., T\}$ to maximize utility:

$$u_{ijt} = \gamma_{is} d_{jt} + \alpha_i^1 pri_{jt} + \alpha_i^2 ads_{jt} + \beta_i' x_{jt} + \eta_{jt} + \varepsilon_{ijt} \tag{4.2}$$

u_{ijt} denotes the indirect utility that consumer i receives from consuming car model j in period t. d_{jt} is the degree of design differentiation of car model j in its brand in period t.γ_{is} captures consumer i's preferences for design differentiation of an s-end car model, where $s \in \{h = \text{high-end}, l = \text{low-end}\}$. pri_{jt} and ads_{jt} are log-transformed prices and advertising expenditure of car model j in period t. x_{jt} is a (column) vector of functional attributes of car model j in period t. It includes horsepower, miles per gallon, size, reliability, safety, and dummy variables that indicate if the car model is a high-end product (versus a low-end product), a coupe (versus a sedan), and a regular car (versus a sporty/specialty car). α_i^1, α_i^2, and β_i are two scalars and a (column) vector of consumer i's parameters for prices, advertising, and functional attributes, respectively. We allow consumer preferences to vary as a function of unobserved individual characteristics v_i. Specifically, we model individual coefficients to follow a normal distribution with mean coefficients $\alpha = [\alpha^1 \alpha^2]'$ and β:

$$\begin{pmatrix} \alpha_i \\ \beta_i \end{pmatrix} = \begin{pmatrix} \alpha \\ \beta \end{pmatrix} + \Sigma v_i, \qquad v_i \sim P_v(v) \tag{4.3}$$

where $P_v(\cdot)$ is the distribution of v_i. We assume that it is a standard multivariate normal distribution. We can rewrite (4.2) as

$$\begin{aligned} u_{ijt} &= \gamma_s d_{jt} + \alpha^1 pri_{jt} + \alpha^2 ads_{jt} + \beta' x_{jt} + \eta_{jt} \\ &\quad + \Delta\gamma_{is} d_{jt} + \Delta\alpha_i^1 pri_{jt} + \Delta\alpha_i^2 ads_{jt} + \Delta\beta_i' x_{jt} + \varepsilon_{ijt} \end{aligned} \tag{4.4}$$

where $\gamma_s d_{jt} + \alpha^1 pri_{jt} + \alpha^2 ads_{jt} + \beta' x_{jt} + \eta_{jt}$ are the mean utility that consumers derive from car model j in time t, and $\Delta\gamma_{is} d_{jt} + \Delta\alpha_i^1 pri_{jt} + \Delta\alpha_i^2 ads_{jt} + \Delta\beta_i' x_{jt}$ are the individual consumer i's deviation from the mean utility. Our focal interest is in $\gamma_s, s \in \{h, l\}$, i.e., the impact of design differentiation on consumer preferences for high-end and low-end products separately. Our hypothesis H_1 states that $\gamma_h > 0$ and $\gamma_l < 0$.[†]

The term η_{jt} in (4.2) captures unobserved demand factors of car model j in period t. ε_{ijt} is the idiosyncratic error term. We normalize the intrinsic utility of the outside good to zero and the total utility of the outside good is only the idiosyncratic error term: $u_{i0t} = \varepsilon_{i0t}$. We further assume that ε_{ijt} follows an i.i.d. Type I extreme value distribution. We assume that each consumer purchases one car model that gives the highest utility. The set of consumers that purchase car model j in time t is:

$$A_{jt} = \{(v_i; \varepsilon_{i0t}, ..., \varepsilon_{iJt}) | u_{ijt} \geq u_{ilt} \quad \forall l = 0, 1, ..., J\} \tag{4.5}$$

The market share of the car model j in time t is integrating over the mass of consumers in

[†]Essentially, we are interested in the main effect of design differentiation (d) on consumer preferences and its interaction with the dummy variable that indicates if a product is a high-end product (versus a low-end product). Our hypothesis (H_1) is equivalent to that the base effect of design differentiation on consumer preferences is negative; however, a product being a high-end product positively moderates the main effect of design differentiation on consumer preferences such that the overall effect of design differentiation of a high-end product on consumer preferences is positive.

the region A_{jt}:

$$s_{jt} = \int_{A_{jt}} dP_{\varepsilon}(\varepsilon) dP_{v}(v) \tag{4.6}$$

We account for potential erogeneity of independent variables in the model. In the following subsection, we lay out the identification strategy, discussing sources of endogeneity problems and how we address them.

4.2.3 Identification

In an ideal and controlled setting, we would like brands to sell the same set of high-end and low-end car models in two similar geographic markets, where in one market brands use the same design while in the other market brands use different designs. This setting would allow us to clearly assess the effect of design differentiation on consumer preferences and choices. However, brands do not vary design across geographic markets, which can confuse consumers and obscure brand image. With data of 207 car models sold in 120 months, we observe variations in car design across car models and changes in car design over time. We rely on cross-sectional variations across car models and time-series variations within car models to identify the parameters of design variables as well as other structural parameters in Equation (4.2). Particularly, the effect of design differentiation on consumer preferences is identified by variations in the inverted market share across car models and across months that change with the variations in the design differentiation variable across car models and across months, after controlling for other factors that impact market share.

We acknowledge endogeneity problems of short-term decision variables including prices and advertising activities. Prices are likely endogenous for two reasons: omitted variables and simultaneity. First, there may be product quality attributes that are unobserved to researchers but considered by car makers to set prices and considered by consumers to choose cars. Such unobserved quality is included in the error term, η_{jt}, which induces correlation between the error term and prices, making prices endogenous. Second, prices are simultaneously determined by the demand side and car makers' profit-maximizing behavior on the supply side. Without explicitly modeling the supply side, prices are endogenous due to simultaneity. Similarly, advertising activities may also be endogenous, as car makers may purposely advertise car models with certain unobserved characteristics in a period.

We take three steps to address these endogeneity problems. First, we use brand fixed effects to control for any brand level unobserved factors that impact prices, advertising, and market shares.[‡] Second, we use month fixed effects to control for seasonality and unobserved month-specific factors that impact prices, advertising, and market shares. However, there could still be correlations between the error term η_{jt} and prices or advertising on dimensions that these fixed effects have not controlled for. We use instrument variables to control for potential sources of endogeneity on these dimensions.

Cost shifters from the supply side would be ideal instruments for prices and advertis-

[‡]Alternatively, one could use car model specific fixed effects to control for unobserved factors at the car model level. However, the drawback of this approach is that car model fixed effects would absorb cross-sectional variations and only rely on time-series variations within car models for identification. However, car design does not change frequently. On average, the life cycle of a car design is seven years with a mid-life refresh (Weber 2009). Certain car models in our dataset have not changed design in the sample period. Hence, variations in the design variable are largely from the cross-sectional dimension. We use brand fixed effects to preserve variations in design variable while controlling for unobserved time-invariant factors at the brand level.

ing as they are not correlated with unobserved demand factors but correlated with prices and advertising levels. Positive shifters of production costs are expected to be positively correlated with prices and positive shifters of advertising costs are expected to be negatively correlated with advertising levels. We use the unit cost of advertising across media (cable TV, network TV, daily magazines, and national newspapers) that Ad$pender reports as instruments for advertising expenditure.

However, data on production cost shifters are not available. To address endogeneity problems of prices, the most popular identifying assumption used in prior research is that the locations of products in the characteristics space is exogenous, or at least determined prior to the revelation of consumers' valuation of the unobserved product characteristics (Nevo 2000). We adopt this identifying assumption. We assume that car attributes, including design characteristics, are determined prior to the revelation of consumers' valuation of the unobserved product characteristics. Based on this assumption, we follow prior research and use observed car characteristics to derive proper instruments for prices (Berry et al. 1995, Sudhir 2001). For example, to create a set of instruments for prices of car model j of brand i using horsepower, we compute the average horsepower of brand i's car models other than j to be the own-brand horsepower instrument variable. We also compute the average horsepower of all car models of all other brands to be the other-brand horsepower instrument variable. We derive two sets of own-brand and other-brand horsepower instruments using two ways to group brands, the first based on country of origin and (regular or non-regular) car type, the second based on country of origin and (luxury or econoour) classification. As a result, we derive four instruments based on each functional attribute variable. With the instruments, we estimate the model using GMM methods (see Nevo 2000 for details). Model estimates are shown in Table 4.2.

4.2.4 Empirical Findings

We begin with estimating a model without design differentiation variables (Model 1) and then add design differentiation variables to the model (Model 2). This sequential analysis helps us assess the change in the explanatory and predictive power of the model by incorporating the design aspect of products. Values of AIC and BIC show that Model 2 fits the data better than Model 1, suggesting that including design differentiation variables helps us better explain consumer preferences and predict consumer choices. Now we interpret results in Model 2.

Table 4.2: Demand Model Estimates

Variables	Model 1 (without d)	Model 2 (with d)
Intercept	$28.14(3.81)^{\ddagger}$	$30.14(4.10)^{\ddagger}$
High-End Design Differentiation (d_h)		$0.24(0.14)^{*}$
Low-End Design Differentiation (d_l)		$-0.40(0.19)^{\dagger}$
High-End (*hig*)	$1.89(0.18)^{\ddagger}$	$1.01(0.35)^{\ddagger}$
Price (*pri*)	$-5.46(0.36)^{\ddagger}$	$-6.08(0.54)^{\ddagger}$
Advertising (*ads*)	$1.77(0.12)^{\ddagger}$	$1.77(0.13)^{\ddagger}$
Horsepower (*hp*)	$0.26(0.05)^{\ddagger}$	$0.23(0.04)^{\ddagger}$
Miles Per Gallon (*mpg*)	$-0.02(0.02)$	$-0.02(0.02)$
Size (*siz*)	$3.42(0.42)^{\ddagger}$	$3.54(0.48)^{\ddagger}$
Reliability (*rel*)	$0.23(0.04)^{\ddagger}$	$0.23(0.04)^{\ddagger}$
Safety (*saf*)	$0.29(0.05)^{\ddagger}$	$0.32(0.05)^{\ddagger}$
Regular (*reg*)	$0.66(0.14)^{\ddagger}$	$0.70(0.13)^{\ddagger}$
Coupe (*cou*)	$0.63(0.08)^{\ddagger}$	$0.60(0.08)^{\ddagger}$
AIC	12,270	12,189
BIC	12,686	12,635

$^{*}p < 0.10$, $^{\dagger}p < 0.05$, $^{\ddagger}p < 0.01$. () negative value.

$^{*}p < 0.10$, $^{\dagger}p < 0.05$, $^{\ddagger}p < 0.01$.

Estimates for brand fixed effects and month fixed effects are not reported due to space limits.

First stage regression of prices on instruments: $R^2 = 0.88$, $F(83, 16184) = 1691$, $p < 0.001$.

First stage regression of advertising on instruments: $R^2 = 0.51$, $F(83, 16184) = 200.85$, $p < 0.001$.

We present the effects of design differentiation on preferences for high-end and low-end products separately. The coefficient of design differentiation for high-end products (d_h) is significantly positive, while the coefficient of design differentiation for low-end products (d_l) is significantly negative, which supports H_1. In addition, the coefficient of the high-end dummy variable (*hig*) is significantly positive, suggesting that consumers derive higher utility from consuming a high-end product compared to a low-end product. Price has a significant and negative effect on preferences, whereas advertising exerts a significant and positive effect on preferences. Estimates of the coefficients of functional attributes are all significant and show that consumers prefer higher fuel efficiency, larger sizes, higher reliability, and safer cars. Consumers also prefer regular cars over sporty/specialty cars, and prefer coupes over sedans.

Overall, this empirical analysis shows that in making car purchase decisions, design differentiation plays an important role in shaping consumer preferences for cars. Consistent with H_1, if a brand diversifies design, consumer preferences for the brand's high-end products increase while preferences for the brand's low-end products decrease. In other words, consumers prefer high-end products to look more differentiated but prefer low-end products to look less differentiated. The opposing preferences presents brands a product design dilemma - should brands diversify design to improve the appeal of its high-end products or unify design to improve the appeal of its low-end products? We are going to address this question using a game-theoretic model in the next section.

4.3 A Model of Brands' Design Differentiation Strategy

In this section, we lay out the setup of the main game-theoretic model, present analysis, and discuss results. We begin with the simplest possible model to seek qualitative insights. In §4.4, we will generalize the base model in several ways to show the robustness of findings and seek new insights.

4.3.1 Model Setup

Consider a market with two competing brands indexed by $i \in \{A, B\}$ that sell status goods such as cars, watches, and handbags.[§] Each brand sells a high-end product and a low-end product to consumers in two market segments indexed by $s \in \{h, l\}$[¶]. We standardize the total size of two markets to 1 and use α to represent the size of the high-end market. Then the size of the low-end market is $1-\alpha$. The product is characterized by two attributes: functionality and exterior design. Functionalities, such as safety features of cars, weight of watches, and sizes of handbags provide intrinsic utilitarian value to consumers, while the exterior design influences the status value of consumption. We discuss each aspect separately.

Intrinsic Utility. Consumers have heterogeneous preferences for the functionality of products. For example, some consumers may prefer heavier watches, bigger handbags, safer and heavier cars that are less fuel-efficient while other consumers may prefer the

[§]For completeness, we also examine the design strategy of a monopolist. Details are included in the Appendix.

[¶]In this paper, we use markets or market segments to refer to the social and demographic segments of consumers that purchase high-end and low-end products respectively. In the base model, we assume that high-end consumers only purchase a high-end product and low-end consumers only purchase a low-end product. We will relax this assumption in §4.4.4 to allow consumers to switch between segments.

opposite. We formulate this consumer heterogeneity by assuming that consumers in market s are distributed on a Hotelling line with range $[0,1]$, according to a continuous distribution function $f_s(\cdot)$ with a cumulative distribution function $F_s(\cdot)$. A consumer's location θ on the line represents the ideal functionality for the consumer. The functionality provided by a product is indicated by the location of the product on the line. We denote the location of brand A's product by a_s and brand B's product by b_s. A consumer incurs a disutility for consuming a product whose functionality is not ideal. We capture this dis-utility of mis-match by the formulation that a consumer incurs a mis-match transportation cost from the consumer's location to the product's location. We assume the mis-match cost is quadratic in the consumer's distance to the product. If a consumer at θ_s purchases the product located at a_s, then the mis-match cost is $t_s(\theta_s - a_s)^2$, where t_s measures the degree of consumer heterogeneity or the intensity of competition in market s. A higher t_s represents greater consumer heterogeneity and less intensive competition. Let p_{is} denote the price of brand $i's$ product sold in market s. The intrinsic utility that the consumer at θ_s derives from purchasing A's s-end product at price p_{as} is $r_s - t_s(\theta_s - a_s)^2 - p_{as}$, where r_s is the base utility from consuming the s-end product. The intrinsic utility from purchasing B's s-end product at price p_{bs} is $r_s - t_s(\theta_s - b_s)^2 - p_{bs}$.

Status Utility. In addition to the intrinsic utility, consumers also derive a status utility from consuming a status good. The status utility provided by high-end and low-end products is influenced by the exterior design differentiation between them. To simply analysis, we assume each brand makes a binary design differentiation decision. Let d_i

denote brand $i's$ exterior design differentiation strategy. If $d_i = 0$, it indicates that brand i unifies design so that its high-end and low-end products look the same. If $d_i = 1$, it indicates that brand i diversifies design so that its high-end and low-end products look different. Design diversification is costly and the cost is denoted by $m > 0$.

Based on the empirical results that support H_1, we assume that if a brand diversifies design, it increases the social value of the brand's high-end product and the magnitude of increase is denoted by the parameter γ_h. Meanwhile, design diversifications decreases the social value of the brand's low-end product and the magnitude of the decrease is denoted by γ_l. Hence, γ_h represent high-end consumers' preferences for design diversification γ_l represent low-end consumers' preferences for design unification. We normalize the base status utility of products to zero. The total utility from consuming a product is the summation of the intrinsic utility and the status utility. As a result, the total utility that a consumer at θ_h receives from consuming brand A's high-end product purchased at price p_{ah} is $r_h - t_h(\theta_h - a_h)^2 - p_{ah} + \gamma_h d_a$. The total utility that a consumer at θ_l receives from purchasing brand A's low-end product at price p_{al} is $r_l - t_l(\theta_l - a_l)^2 - p_{al} - \gamma_l d_a$. The total utility from consuming brand B's products can be defined analogously.

The sequence of the game is as follows. There are three stages in the game. In the first stage, brands simultaneously make their exterior design differentiation decision by choosing between unification ($d_i = 0$) and diversification ($d_i = 1$), which will become common knowledge to both brands. In §4.4.1, we will consider situations where brands make the design decision sequentially. In the second stage, brands simultaneously set prices of their products. In the last stage, consumers in each market observe design and prices of the two products that brands offer for their market and decide from which brand to buy the product. This sequence of moves reflects the process of decision-making in the development of new products, as brands make product design decisions prior to setting prices. It is also appropriate since design strategies are less flexible, while prices are easier to change. In the main model, we assume that the functionalities of products have been exogenously determined and are symmetric between brands, i.e., $a_s = 1 - b_s,\ s \in \{h, l\}$. In §4.4.2, we will allow brands to choose functionalities of products given their exterior design decisions.

Lastly, we account for the fact that it is more costly to produce a high-end product than a low-end product. We standardize the marginal cost to produce a low-end product to zero and use c to represent the incremental marginal cost to produce a high-end product. We will solve for the sub-game perfect Nash equilibrium backward.

4.3.2 Analysis and Results

Let θ_h denote the location of the marginal consumer in the high-end market (see Figure 4.3). This marginal consumer is indifferent between buying A's high-end product and B's high-end product. We must have that:

$$r_h - t_h(\theta_h - a_h)^2 - p_{ah} + \gamma_h d_a = r_h - t_h(\theta_h - b_h)^2 - p_{bh} + \gamma_h d_b \tag{4.7}$$

$$\theta_h = \frac{a_h + b_h}{2} - \frac{p_{ah} - p_{bh}}{2t_h(b_h - a_h)} + \frac{\gamma_h(d_a - d_b)}{2t_h(b_h - a_h)} \tag{4.8}$$

The left hand side of Equation (4.7) is the total utility of buying the high-end product from brand A. It comprises of the intrinsic utility $r_h - t_h(\theta_h - a_h)^2 - p_{ah}$ and the status utility $\gamma_h d_a$ that is increasing in d_a, i.e. design diversification from A's low-end product. The right hand side of Equation (4.7) is the total utility of buying the high-end product from brand B. The intrinsic utility is $r_h - t_h(\theta_h - b_h)^2 - p_{bh}$. The status utility $\gamma_h d_b$ is increasing in d_b, i.e., design diversification from B's low-end product. Equation (4.8) gives the location of the marginal consumer. The first two terms represent the location of this marginal consumer when $\gamma_h = 0$, i.e., high-end consumers have no preferences for design diversification. The last term suggests that holding prices constant, θ_h is increasing in d_a and decreasing in d_b. It suggests that design diversification of a brand increases sales of the brand's high-end product, as design diversification enhances the status utility provided by a high-end product.

Now let us examine the low-end market. The location of the marginal consumer in the low-end market is denoted by θ_l. This marginal consumer is indifferent between buying A's low-end product and B's low-end product. We must have that:

$$r_l - t_l(\theta_l - a_l)^2 - p_{al} - \gamma_l d_a = r_l - t_l(\theta_l - b_l)^2 - p_{bl} - \gamma_l d_b \tag{4.9}$$

$$\theta_l = \frac{a_l + b_l}{2} - \frac{p_{al} - p_{bl}}{2t_l(b_l - a_l)} - \frac{\gamma_l(d_a - d_b)}{2t_l(b_l - a_l)} \tag{4.10}$$

The left hand side of Equation (4.9) is the total utility of buying brand A's low-end product. Like in the high-end market, the intrinsic utility is $r_l - t_l(\theta_l - a_l)^2 - p_{al}$. Unlike in the high-end market, the status utility is decreasing in design diversification denoted by d_a. Similarly, the right hand side of Equation (4.9) is the total utility of buying B's low-end product. The intrinsic utility is $r_l - t_l(\theta_l - b_l)^2 - p_{bl}$, and the status utility is $-\gamma_l d_b$, declining with d_b. Equation (4.10) shows that the location of the marginal consumer in the low-end market, i.e., θ_l, decreases with d_a but increases with d_b. This suggests that holding prices constant, sales of a brand in the low-end market is decreasing in the brand's design diversification and increasing in the competitor's design diversification, opposite to the effects of design diversification in the high-end market.

Brands make exterior design and pricing decisions to maximize their respective profit function given below:

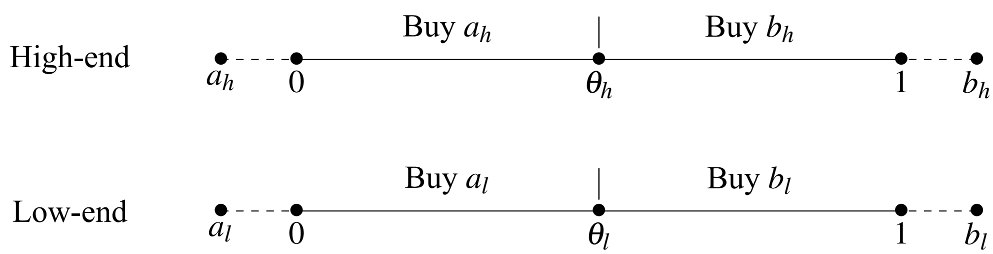
$$\Pi_a = \alpha(p_{ah}-c)F_h(\theta_h)+(1-\alpha)p_{al}F_l(\theta_l)-m\cdot d_a \tag{4.11}$$

$$\Pi_b = \alpha(p_{bh}-c)(1-F_h(\theta_h))+(1-\alpha)p_{bl}(1-F_l(\theta_l))-m\cdot d_b \tag{4.12}$$

With this setup, we analyze optimal pricing and profits under symmetric and asymmetric exterior design differentiation regimes. Then, we will compare brand profits in symmetric and asymmetric regimes to derive the equilibrium design strategy.

Symmetric Design Strategies. Consider the case that brands adopt symmetric design strategies, i.e., design strategies of two brands are the same so that $d_a = d_b = d$. We assume the distribution of consumers in each market, $f_s(\cdot)$, is a symmetric log-concave function. Using first order conditions and symmetry, we obtain the equilibrium prices: $p_h^* = \frac{t_h(b_h-a_h)}{f_h(\frac{1}{2})}+c$ and $p_l^* = \frac{t_l(b_l-a_l)}{f_l(\frac{1}{2})}$. In equilibrium, $\theta_h^* = \theta_l^* = \frac{1}{2}$. Brand profits under this symmetric design regime are $\Pi^* = \frac{\alpha t_h(b_h-a_h)}{2f_h(\frac{1}{2})}+\frac{(1-\alpha)t_l(b_l-a_l)}{2f_l(\frac{1}{2})}-m\cdot d$. Note that when two brands adopt symmetric design strategies, the impact of design on sales and prices in each market cancels out. Consequently, a symmetric change in design strategies by both brands does not increase equilibrium prices or sales. Hence, costly design diversification becomes unnecessary and reduces profits. Brands are better off when they both unify the design of high-end and low-end products. We state this result in Lemma 1 below:

Figure 4.3: Purchase Pattern with Symmetric Design Strategies



Lemma 2 *When brands choose the same design strategy, profits are higher when both brands unify design than when both brands diversify design.*

Asymmetric Design Strategies. Now consider situations where competing brands adopt asymmetric design strategies. Without loss of generality, assume brand A unifies design while brand B diversifies design, i.e., $d_a = 0$ and $d_b = 1$. We consider situations where the cost of design diversification is not prohibitive, i.e., $m < \frac{\alpha\gamma_h}{3}\left(1 - \frac{\gamma_h}{9t_h}\right)$ so that brands sometimes have incentives to diversify design. We also consider situations where brands are active in both markets, which requires that $\theta_s \in (0,1), s \in \{h,l\}$. To derive equilibrium in this asymmetric case, we further assume that $f_s(\cdot)$ is uniform. We present our results blow and detailed proof in the Appendix.

Proposition 14 *As long as $\frac{\alpha}{1-\alpha} \cdot \frac{t_h}{t_l} \cdot \frac{b_h - a_h}{b_l - a_l} \in \left(\frac{1}{2}, 3\right)$, adopting asymmetric design strategies leads to a win-win outcome for competing brands if $\gamma_h \in (\hat{\gamma}_1, \hat{\gamma}_2)$. $\hat{\gamma}_1$ and $\hat{\gamma}_2$ both increase with γ_l and $\hat{\gamma}_2 > \hat{\gamma}_1$ when γ_l is sufficiently large.*

This proposition shows that adopting asymmetric exterior design strategies can lead to a win-win outcome for symmetric brands. It is a win-win outcome in the sense that, by adopting different design strategies, both brands obtain higher profits than if they adopted the same design strategy in this situation. Hence, it is profitable for competing brands to choose different design strategies. The main intuition is that the asymmetry in brands' exterior design strategy allows brands to avoid head-to-head competition in both markets. Instead, each brand gains a comparative advantage in a different market. Specifically, the brand that unifies design has a comparative advantage in the low-end market. This is because, the brand's low-end product shares the same design as its high-end product and therefore provides a higher status utility than the competing low-end product that carries a different design from its high-end counterpart. On the other hand, the brand that diversifies design has a comparative advantage in the high-end market. This is because compared to the competing high-end product that looks the same as its low-end counterpart, the high-end product that carries a distinctive design from its low-end counterpart provides a higher status utility. As a result, brands sell more of their comparatively advantageous product at higher prices. At the same time, brands sell less of their comparatively disadvantageous product at lower prices. The gain in the advantageous market can outweigh the loss in the disadvantageous market. Therefore, compared to the case that brands choose symmetric design strategies, both brands can make higher profits by adopting asymmetric design strategies, which is a win-win outcome.

This win-win outcome arises when the counteracting preferences for design differentiation by high-end and low-end consumers are both sufficiently strong (see Region (S,D) win-win in Figure 4.4). The reason is that when γ_h is sufficiently strong, the brand that diversifies design can establish a comparative advantage in the high-end market, as high-end consumers strongly prefer the high status utility associated with the distinct design of its high-end product over the competing product. Hence, a strong γ_h ensures that adopting asymmetric design strategies is profitable for the brand that diversifies design. By the same logic, a strong γ_l ensures that adopting asymmetric design strategies is profitable for the brand that unifies design and establishes a comparative advantage in the low-end market. For asymmetric design strategies to improve profits of both brands, γ_h and γ_l need to be sufficiently strong so that both brands make enough higher profits from its advantageous market to offset the loss in its disadvantageous market.

A sufficient condition for the win-win situation to arise is that the overall conditions of the high-end and low-end markets are not too different. Specifically, we measure the relative market conditions in terms of relative market size, i.e., $\frac{\alpha}{1-\alpha}$, relative intensity of competition, i.e., $\frac{t_h}{t_l}$, and relative differentiation in functionality, i.e., $\frac{b_h-a_h}{b_l-a_l}$. As long as the overall characteristics of two markets are close to being symmetric, i.e., the product of the three indices is around 1, specifically, $\frac{\alpha}{1-\alpha} \cdot \frac{t_h}{t_l} \cdot \frac{b_h-a_h}{b_l-a_l} \in \left(\frac{1}{2}, 3\right)$, brands can both be better off by adopting asymmetric design strategies. Let us understand the intuition behind this result. Suppose $\frac{\alpha}{1-\alpha} \cdot \frac{t_h}{t_l} \cdot \frac{b_h-a_h}{b_l-a_l}$ is sufficiently large. It implies that the high-end market is much more favorable than the low-end market, with either a much larger market share, much softer competition, or much greater differentiation in the functionality of competing products than those in the low-end market. These favorable conditions motivate brands to expand presence in the high-end market instead of the low-end market. Consequently, the brand that loses comparative advantage in the high-end market due to design unification is worse off, and the win-win situation cannot arise. Conversely, if $\frac{\alpha}{1-\alpha} \cdot \frac{t_h}{t_l} \cdot \frac{b_h - a_h}{b_l - a_l}$ is sufficiently small, then the low-end market becomes much more favorable than the high-end market. As a result, the brand that loses comparative advantage in the low-end market due to design diversification is worse off and the win-win situation also cannot arise. In addition, since diversification is costly, the condition for the diversifying brand to win is more stringent than the condition for the unifying brand to win. Hence, the market condition of the high-end market can be much more favorable than the low-end market, which explains why the range $(\frac{1}{2}, 3)$ is skewed in favor of the diversifying brand that has a comparative advantage in the high-end market.

To summarize, the above discussion suggests that *the intra-brand design differentiation strategy can serve as a new dimension of inter-brand differentiation. Choosing different design strategies, competing brands can soften competition and both obtain higher profits.* This insight provides a new perspective for researchers to examine competition and product differentiation. It also points to a new opportunity for brands to improve profits. One interesting question that follows is: When is this type of brand differentiation most beneficial? We address this question in the proposition below.

Proposition 15 *Asymmetric design strategies are more profitable than symmetric design strategies when competing products in the same market are less differentiated in functionality and competition is more intense.*

This proposition shows that the benefit of differentiation in exterior design strategy is larger when brands are not sufficiently differentiated from each other in the functionality attribute of competing products. This is because when competing products are less differentiated from each other, consumers' product choices are more influenced by the status utility provided by products. As a result, the effects of design strategy become stronger and asymmetric design strategies improve profits to a greater degree. In addition, when competition is more intense, which happens when consumers have more homogeneous taste for functionality, brands have stronger incentives to pursue differentiation in exterior design strategy. This is despite the fact that intensive competition alone reduces brand profits in either symmetric or asymmetric design regime. Compared to adopting symmetric design strategies, more intensive competition hurts brands that adopt asymmetric design strategies less because brands can leverage intensive competition to coordinate market power more easily. To see this, the equilibrium market cutoff points in two markets are $\theta_h = \frac{1}{2} - \frac{\gamma_h}{6t_h(b_h - a_h)}$ and $\theta_l = \frac{1}{2} + \frac{\gamma_l}{6t_l(b_l - a_l)}$, deviating more from the middle of the line in opposite directions as competition becomes more intense, i.e., as t_s decreases. Although intensive competition reduces prices that brands can charge in either market, brands gain more market share in the market in which it sells a competitively advantageous product. Hence, this positive effect mitigates the negative impact of competition and makes asymmetric design strategies more profitable compared to symmetric design strategies.

Equilibrium Design Strategies. The above analysis illustrates the benefits of asymmetric design strategies over symmetric design strategies. Now we compare brands' equilibrium profits under symmetric and asymmetric design strategies to solve for brands' endogenous design choices in equilibrium.

Proposition 16 *Brands' equilibrium design choices are*

(a) asymmetric design strategies when $\gamma_h \in (\hat{\gamma}_1, \hat{\gamma}_3)$*, where* $\hat{\gamma}_3 > \max(\hat{\gamma}_1, \hat{\gamma}_2)$ *and is increasing in* γ_l*;*

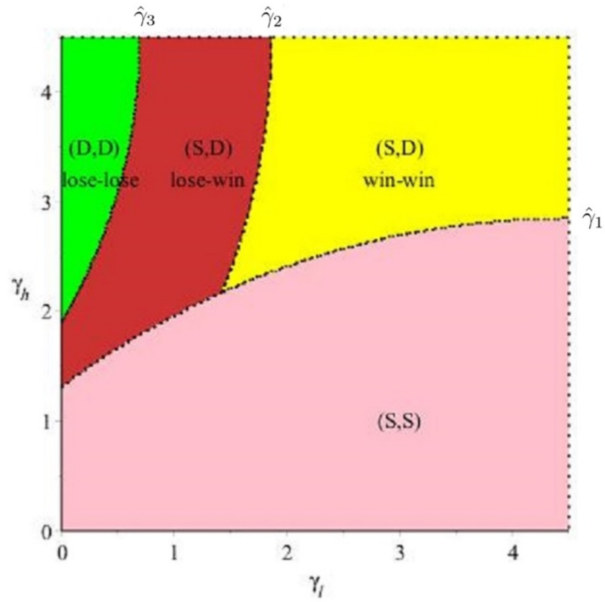
(b) symmetric diversification when $\gamma_h \geq \hat{\gamma}_3$*, where a prisoner's dilemma arises;*

(c) symmetric unification when $\gamma_h \leq \hat{\gamma}_1$*.*

Figure 4.4 depicts the regions of γ_h and γ_l where symmetric unification, symmetric diversification, or asymmetric design strategies arise in equilibrium. Part (a) of the proposition shows that when high-end consumers' preferences for design diversification are moderately strong, brands choose asymmetric design strategies (see Region (S,D)). Furthermore, $\hat{\gamma}_3 > \max(\hat{\gamma}_1, \hat{\gamma}_2)$. Hence, the region where the win-win situation arises (i.e., $\gamma_h \in (\hat{\gamma}_1, \hat{\gamma}_2)$) is a subset of the region where brands choose asymmetric design strategies (i.e., $\gamma_h \in (\hat{\gamma}_1, \hat{\gamma}_3)$). This result confirms that the win-win situation can arise in equilibrium. This result also provides an explanation to the puzzling observations that in the same industry or market conditions, some brands unify design while other brands diversify design. In addition, it also suggests that depending on which design strategy the competitor adopts, it may be beneficial for a brand to adopt either design unification or design diversification that is asymmetric with the competitor's design strategy.

It is useful to note that if $\gamma_h \in (\max(\hat{\gamma}_1, \hat{\gamma}_2), \hat{\gamma}_3)$, the brand that unifies design loses and the brand that diversifies design wins, compared to profits with symmetric unification. This is because in this region, brand A has incentives to deviate from symmetric diversifica-

Figure 4.4: Equilibrium Simultaneous Design Strategies



tion to unify design. However, γ_h is very strong and decreases brand A's profit. Although A's profit is higher than when it diversifies design and incurs the cost of diversification, A's profit is lower than if both brands commit to unifying design. We illustrate these findings with numerical examples in Table 4.3a and Table 3b that show brands' profits in the respective regions. In both cases, brands endogenously choose asymmetric design strategies. However, only when γ_h is not overly strong, i.e., $\gamma_h \in (\hat{\gamma}_1, \hat{\gamma}_2)$, can both brands make higher profits than choosing symmetric unification.

When high-end consumers have very strong preferences for design diversification, i.e., $\gamma_h \geq \hat{\gamma}_3$, brands face a prisoner's dilemma. As shown by the numerical example in Table 4.3c, it is beneficial for one brand to diversify design, because diversification appeals strongly to high-end consumers. However, when both brands diversify design, both brands are worse off compared to the case when they could commit to design unification (see

Lemma 3). In contrast, when high-end consumers have very low preferences for design diversification, i.e., $\gamma_h < \hat{\gamma}_1$, brands do not have incentives to diversify design. Hence, both brands unify design. Table 4.3d illustrates this outcome with a numerical example.

4.4 Extensions

In this section, we relax several assumptions made in the main model to generalize results and look for new insights.

4.4.1 Sequential Design Decisions

The analysis thus far has shown equilibrium exterior design differentiation strategies when brands make design decisions simultaneously. One may argue that competing products are not always introduced at the same time and brands' design decisions may be made sequentially. Here we examine how the sequential nature of decision-making impacts equilibrium design decisions. Suppose that in the first stage of the game, the first-mover (Stackelberg leader) chooses its exterior design strategy. After observing the leader's design choice, the follower chooses its exterior design strategy. In the second stage, the leader and the follower observe each other's design choice and simultaneously set prices.

Proposition 17 *When brands choose design strategies sequentially, symmetric unification, symmetric diversification, and the asymmetric design choices arise under the same condition as when brands choose design strategies simultaneously. When asymmetric design choices arise, the first mover makes higher profits than the follower does and chooses design unification if and only if* $m + \frac{2(1-\alpha)\gamma_l}{3} > \frac{2\alpha\gamma_h}{3}$.

Table 4.3: Numerical Illustrations of Equilibrium Design Choices

Table 4.3a: γ_h and γ_l Both Strong $\gamma_h \in (\hat{\gamma}_1, \hat{\gamma}_2)$ *(S,D) win-win			
$\gamma_h = 3$ $\gamma_l = 3$	Brand B	S	D
Brand A	S	$(0.75, 0.75)$	$(1.08, 0.83)^*$
	D	$(0.83, 1.08)^*$	$(0.50, 0.50)$

Table 4.3b: γ_h Strong, γ_l Moderately Strong $\gamma_h \in (\max(\hat{\gamma}_1, \hat{\gamma}_2), \hat{\gamma}_3)$ *(S,D) lose-win			
$\gamma_h = 3$ $\gamma_l = 1$	Brand B	S	D
Brand A	S	$(0.75, 0.75)$	$(0.60, 1.02)^*$
	D	$(1.02, 0.60)^*$	$(0.50, 0.50)$

Table 4.3c: γ_h Strong, γ_l Weak $\gamma_h \geq \hat{\gamma}_3$ *(D,D) lose-lose			
$\gamma_h = 3$ $\gamma_l = \frac{1}{3}$	Brand B	S	D
Brand A	S	$(0.75, 0.75)$	$(0.47, 1.11)$
	D	$(1.11, 0.47)$	$(0.50, 0.50)^*$

Table 4.3d: γ_h Weak, γ_l Strong $\gamma_h \leq \hat{\gamma}_1$ *(S,S) baseline			
$\gamma_h = \frac{1}{3}$ $\gamma_l = 3$	Brand B	S	D
Brand A	S	$(0.75, 0.75)^*$	$(1.36, 0.22)$
	D	$(0.22, 1.36)$	$(0.50, 0.50)$

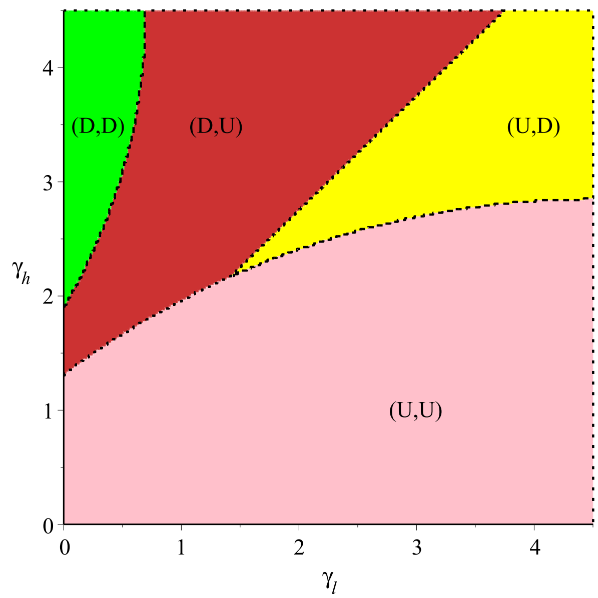
$\alpha = \frac{1}{2}$, $t_h = t_l = 1$, $a_h = a_l = -\frac{1}{4}$, $b_h = b_l = \frac{5}{4}$, $m = \frac{1}{4}$

The first part of the proposition confirms that the optimal exterior design strategies hold under the same conditions as when brands make design decisions simultaneously. The second part of the proposition shows that the leader enjoys the first-mover advantage by selecting design strategy in the region where asymmetric design strategies arise. Hence, the first mover makes higher profits than the follower. The condition for the first mover to choose unification over diversification represents the tradeoff that it faces. By unifying design, the brand can avoid the cost of diversification. In addition, unification is appealing for low-end consumers. When diversification is more costly, low-end consumers have stronger preferences for unification; or when the size of the low-end market is larger, the first mover has stronger incentives to unify design. On the other hand, unification decreases the status utility of the high-end product. When high-end consumers have stronger preferences for diversification, or the size of the high-end market is larger, the first mover has lower incentives to unify design. Overall, the first mover unifies design when the former aspect dominates the latter, i.e., $m+\frac{2(1-\alpha)\gamma_l}{3} > \frac{2\alpha\gamma_h}{3}$ (see Figure 4.5).

4.4.2 Endogenous Functionalities

In the above analysis we treat the functionalities, i.e., locations of products, as exogenous and invariant with brands' exterior design strategies. Now we examine whether brands have incentives to adjust functionalities of products in response to exterior design strategies. To do so, we allow brands to simultaneously choose locations a_s and b_s where $s \in \{h,l\}$, after observing exterior design strategies but before setting prices, as functional aspects of products are less flexible to change than prices. I solve for the equilibrium func-

Figure 4.5: Equilibrium Sequential Design Strategies

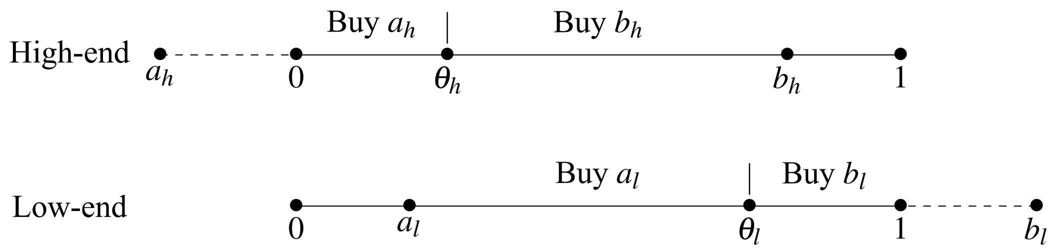


tionalities using first order conditions (see details in the Appendix).

Proposition 18 *When brands choose different design strategies, the brand that diversifies design produces a more mainstream high-end product and a more niche low-end product; the brand that unifies design produces a more niche high-end product and a more mainstream low-end product.*

The intuition is as follows: Suppose brand A unifies design and brand B diversifies design, then the status value of B's high-end product increases while the status value of its low-end product decreases. As a result, B's high-end product becomes more appealing and attracts more consumers; then, θ_h shifts to the left. This expansion in consumer base leads to a more diverse set of consumers buying B's high-end product and gives B incentives to provide more mainstream functionalities in its high-end product to cater to the diverse taste of consumers. At the same time, B's low-end product becomes less attractive and θ_l shifts

Figure 4.6: Asymmetric Design Strategy and Endogenous Functionalities



to the right, resulting in a smaller consumer base for B in the low-end market. Moreover, the remaining low-end consumers have a concentrated taste and preference for B's product. In response to this change, B should provide more niche functionalities in its low-end product to better serve the remaining low-end consumers (see Figure 4.6). However, when brands choose symmetric design strategies, as shown in §4.3.2, the impact of symmetric design strategies on consumer choices cancel out. The set of consumers that buy from each brand does not change with brands' symmetric design decisions. Hence, brands' optimal functionalities remain the same in either symmetric unification or symmetric diversification ($a_h^* = a_l^* = -\frac{1}{4}$ and $b_h^* = b_l^* = \frac{5}{4}$ and see Figure 4.3).

4.4.3 Endogenous Preferences for Design Differentiation

In the main model, we represent the degree of consumers' preferences toward design diversification with exogenous parameters γ_s, $s \in \{h, l\}$. Design diversification increases the status utility experienced by high-end consumers by γ_h and decreases the status utility experienced by low-end consumers by γ_l. This formulation is consistent with our empirical findings. However, one may argue that the impact of design diversification on the status utility may depend on how many consumers buy the counterpart product under the same brand. For example, high-end consumers may benefit more from design diversification when there are more low-end consumers who buy the brand's low-end product. However, when there are only a handful of low-end consumers who buy the low-end product, design diversification may not be that beneficial. We modify the main model to account for this possibility. Specifically, we allow diversification to increase the status utility of a brand's high-end product more when there are more low-end consumers that buy the brand's low-end product. In this setup, the location of the marginal high-end consumer at θ_h becomes:

$$r_h - t_h(\theta_h - a_h)^2 - p_{ah} + \gamma_h(1-\alpha)\theta_l^e d_a = r_h - t_h(\theta_h - b_h)^2 - p_{bh} + \gamma_h(1-\alpha)(1-\theta_l^e)d_b \tag{4.13}$$

$$\theta_h = \frac{a_h + b_h}{2} - \frac{p_{ah} - p_{bh}}{2t_h(b_h - a_h)} + \frac{\gamma_h(1-\alpha)\left[d_a\theta_l^e - d_b(1-\theta_l^e)\right]}{2t_h(b_h - a_h)} \tag{4.14}$$

where θ_l^e is the rational expectation of the location of the indifferent low-end consumer. On the other hand, we also allow diversification to decrease the status utility of a brand's low-end product more when there are more high-end consumers that buy the brand's high-end product. The location of the marginal low-end consumer at θ_l becomes:

$$r_l - t_l(\theta_l - a_l)^2 - p_{al} - \gamma_l\alpha\theta_h^e d_a = r_l - t_l(\theta_l - b_l)^2 - p_{bl} - \gamma_l\alpha(1-\theta_h^e)d_b \tag{4.15}$$

$$\theta_l = \frac{a_l + b_l}{2} - \frac{p_{al} - p_{bl}}{2t_l(b_l - a_l)} - \frac{\gamma_l\alpha\left[d_a\theta_h^e - d_b(1-\theta_h^e)\right]}{2t_l(b_l - a_l)} \tag{4.16}$$

where θ_h^e is the rational expectation of the location of the indifferent high-end consumer. Equations (4.14) and (4.16) show that the direction of the impact of design diversification on locations of marginal consumers is consistent with that in the main model, though the magnitude of the impact is moderated by the brand's market share in the other market. We impose rational expectations condition, i.e., $\theta_h^e = \theta_h^*$ and $\theta_l^e = \theta_l^*$, and solve for brand decisions as in the main model (see the Appendix for details). My main results still hold qualitatively. Particularly, asymmetric design strategies can still be a win-win equilibrium outcome when γ_h and γ_l are sufficiently strong, although this region becomes smaller. Endogenous preferences weaken the benefit of asymmetric design choices in two ways. Let us take brand B as an example to illustrate the two effects. B adopts design diversification and the high-end market is its advantageous market. However, B's comparative advantage in the high-end market is mitigated by the decrease in its market size in the low-end market, because as there are fewer low-end consumers that buy from B, B's high-end consumers value design diversification less. This reduces B's profit from the high-end market. Meanwhile, as B's high-end market share increases, design diversification hurts its low-end consumers more, reducing B's profit in the low-end market. As a result, brands gain less profit from adopting asymmetric design strategies.

4.4.4 Intra-brand Switching

In the base model, we assumed that the two market segments are separate, i.e., consumers in the high-end market only buy a high-end product and do not consider buying a low-end product; consumers in the low-end market only buy a low-end product and do not consider buying a high-end product. This assumption is plausible when high-end and low-end consumers have sufficiently different valuations for quality where the quality levels of the high-end and low-end products are sufficiently differentiated (Amaldoss and Jain 2015). In this section, we relax this assumption and consider situations where some consumers may switch between buying the high-end and low-end products when brands choose different design strategies. Specifically, we assume that β fraction of the low-end consumers have strong preferences for design unification, i.e., $\gamma_l' = \gamma_l + \delta$. δ is sufficiently large so that if a brand diversifies design, the utility of the brand's low-end product is sufficiently low that these consumers are better off buying a high-end product than the brand's low-end product. When a brand unifies design, these consumers would buy a low-end product that resembles the design of its high-end counterpart. In this setting, $(1-\alpha)\beta$ fraction of consumers buy high-end products if both brands diversify design, and buy a low-end product as long as a brand unifies design. The remaining $(1-\alpha)(1-\beta)$ fraction of consumers always buy a low-end product.

First consider the symmetric cases. When both brands unify designs, the $(1-\alpha)\beta$ fraction of consumers buy low-end products, as in the main model. Hence, the equilibrium result with symmetric unification in the main model applies. When both brands diversify designs, the $(1-\alpha)\beta$ fraction of consumers buy high-end products. Assuming that the profit margin in the high-end market is larger than the profit margin in the low-end market, i.e., $t_h > t_l$, profits when both brands diversify design are higher as consumers switch to buying high-end products. Now consider the asymmetric design strategies. When brand A unifies design while brand B diversifies design, the $(1-\alpha)\beta$ fraction of consumers buy brand A's low-end product, as these consumers place low values to quality and high values to social image. My analysis shows that the presence of the switching consumers strengthens the main finding that asymmetric design strategies lead to a win-win outcome. We state the finding in the proposition below.

Proposition 19 *As β increases, i.e., more consumers switch between brands, brands make higher profits from adopting asymmetric design strategies.*

The intuition is the following. When brand A unifies design and brand B diversifies design, brand A attracts $(1-\alpha)\beta$ fraction of switching consumers to buy its low-end product that resembles the design of A's high-end product. Given that brand A does not compete with brand B in the switching segment and brand A sells low-end products to these switchers, brand A has incentives to raise the price of the low-end product to exploit the monopoly power in the switching segment. Given that brand A also competes with brand B in the low-end segment, A's incentive to raise the low-end price induces brand B to raise the low-end price. Both the direct effect of a price increase in the low-end segment and strategic effect of softened competition enable both brands to make higher profits from the low-end segment. As β increases, the positive effects on brand profits are stronger. Hence, both brands can make higher profits from adopting asymmetric design strategies. Given that brand profits from adopting the symmetric unification remains the same as in the main model, the above result suggests that asymmetric design strategies lead to stronger win-win outcome, i.e., profits with asymmetric design strategies are much higher than profits with symmetric unifications.

4.5 Conclusion

Luxury products in a wide range of industries are conspicuously consumed and provide status value to consumers. Global expenditure on luxury products exceeded \$1.1 trillion and continues to grow. The exterior design of luxury products is a critical attribute that influences the status value that consumers receive from consuming these products, which in turn affects consumer choices and brand profits. In this paper, we study the optimal exterior design differentiation between high-end and low-end products. We build a game-theoretic model in which design diversification between high-end and low-end products of a brand increases consumer preferences for the high-end product but decreases preferences for the low-end product. We investigate design strategies that brands choose in equilibrium. We also analyze the implications of the exterior design differentiation strategy on equilibrium prices and functionalities of products. Our analysis shows the following insights and provides important managerial implications:

What is the optimal exterior design differentiation strategy? Our results suggest that when low-end consumers strongly prefer design unification and high-end consumers strongly prefer design diversification, brands should choose different design strategies to obtain higher profits. When high-end consumers have weak preferences for design diversification, competing brands should all choose design unification. However, when high-end consumers have strong preferences for design diversification but low-end consumers have weak preferences for design unification, brands have incentives to diversify design; however, both brands make higher profits if they could commit to design unification.

How should brands adjust prices of products based on their design differentiation strategy? We show that when brands adopt different design strategies, brands should adjust prices based on their design strategy. Specifically, the brand that diversifies design should raise prices of their high-end product and reduce prices of their low-end product. In contrast, the brand that unifies design should raise prices of their low-end product and reduce prices of their high-end product.

How should brands adjust functionalities of products based on their design differentiation strategy? We also find that the exterior design decision has important implications on how brands should set the functionalities of products. Specifically, when brands adopt different design strategies, the brand that diversifies design should produce high-end products that have more mainstream functionalities and low-end products that have more niche functionalities; whereas the brand that unifies design should produce low-end products that have more mainstream functionalities and high-end products that have more niche functionalities.

Why do some brands use the same design while other brands use different designs for their high-end and low-end products? Our analysis shows that brands may choose design unification or diversification in different market conditions. Generally, strong preferences for diversification by high-end consumers and favorable market conditions in the high-end market lead brands to diversify design, whereas weak preferences for diversification by high-end consumers and favorable market conditions in the low-end market lead brands to unify design. Moreover, even when brands are in the same industry and face the same situation, it can be profitable for brands to choose different design strategies. We show that when the market conditions of high-end and low-end markets are not too different and the opposing preferences for design diversification by high-end and low-end consumers are both sufficiently strong, competing brands choose different design strategies.

Can design unification be a profitable design strategy? Our analysis shows that when brands choose the same design strategy, unification yields higher profits than diversification. When brands choose different design strategies, some brands need to choose unification while other brands choose diversification to achieve a win-win outcome. In addition, under some conditions, a design leader who can choose design before competitors choose design finds it profitable to unify design. Hence, design unification can, in fact, be a profitable design strategy.

There are several avenues for future research. First, in this paper, we have focused on one specific aspect of exterior product design, i.e., the exterior design differentiation between high-end and low-end products. Future research can investigate other aspects of exterior product design and their implications on consumer choices, brand decisions, and profits. Second, the analysis provides one possible explanation to the dichotomous design choices that brands make. It may be interesting to further explore brand specific characteristics that make one particular design strategy to become more profitable than the other.

5 CONCLUSION

In this dissertation, I show that consumers' social and psychological considerations such as fairness concerns, context-dependency, and social status concerns affect consumers' decision making, which in turn affect firms' strategic marketing decisions such as pricing, upgrade introductions, and design differentiation between product lines. Future research can examine the impact of other social and psychological factors on consumers' decision making and firms' other important decisions.

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APPENDIX A

PROOFS FOR CHAPTER 1

Proof of Lemma 1

Without customer recognition, the two-period model is a repetition of a static game. In each period, the consumer who is indifferent between buying from firm A at a price p_a and firm B at a price p_b is indexed by θ_1 where

$$\begin{aligned} r - t\theta_1 - p_a &= r - t(1-\theta_1) - p_b \\ \theta_1 &= \frac{1}{2} - \frac{p_a - p_b}{2t} \end{aligned} \tag{A1}$$

The profit functions of the two firms are

$$\begin{aligned} \Pi_{a1} &= \theta_1 \cdot p_a \\ \Pi_{b1} &= (1-\theta_1) \cdot p_b \end{aligned} \tag{A2}$$

First order conditions give the equilibrium outcomes: $p_a^* = p_b^* = t$, $\theta_1^* = \frac{1}{2}$, and $\Pi_{a1}^* = \Pi_{b1}^* = \frac{t}{2}$. The total discounted profits over the two periods are $\Pi_a^* = \Pi_b^* = \frac{(1+\delta_f)t}{2}$. $\square$

Proof of the claim that following a symmetric first period equilibrium, poaching prices are lower than past-customer prices

We prove the above claim by considering two types of pricing policy. We first consider symmetric second period pricing policy, i.e., either both firms give discounts to switchers or both firms give discounts to own customers. Then we allow for asymmetric pricing policy, i.e., one firm gives discounts to switchers and another firm gives discounts to own customers. We focus on pure strategy equilibrium.

Claim 1 *With symmetric second period pricing policy, in any pure strategy equilibrium, poaching prices must be lower than past-customer prices.*

Proof: Suppose the claim does not hold and both firms set poaching prices to be strictly higher than past-customer prices, i.e., $a_c^* > a_o^*$ and $b_c^* > b_o^*$, then switching customers experience fairness concerns. The indifferent customer at θ_a becomes:

$$r - t\theta_a - a_o = r - t(1-\theta_a) - b_c - \lambda(b_c - b_o) \tag{A3}$$

$$\theta_a = \frac{1}{2} - \frac{a_o - b_c}{2t} + \frac{\lambda(b_c - b_o)}{2t} \tag{A4}$$

Similarly, the indifferent customer at θ_b becomes:

$$r - t\theta_b - a_c - \lambda(a_c - a_o) = r - t(1-\theta_b) - b_o \tag{A5}$$

$$\theta_b = \frac{1}{2} + \frac{b_o - a_c}{2t} - \frac{\lambda(a_c - a_o)}{2t} \tag{A6}$$

It follows that in equilibrium

$$\theta_a^* - \theta_b^* = \frac{(1+\lambda)(a_c^* - a_o^* + b_c^* - b_o^*)}{2t} > 0 \tag{A7}$$

by the assumption that $a_c^* > a_o^*$ and $b_c^* > b_o^*$.

However, for both firms to poach, we need $\theta_a^* < \theta_1 < \theta_b^*$ which cannot be satisfied in this case. Assume without loss of generality that only firm A poaches i.e., $\theta_b^* > \theta_1$. This implies that $\theta_a^* > \theta_1$ and A can increase its profit by increasing a_o by some $\varepsilon > 0$. This increases profits from its own segment while also decreasing the perceived unfairness by the switcher segment and therefore potentially increasing sales and profits in this segment too. Therefore, this cannot be an equilibrium. Assume neither firm poaches, without loss of generality assume $\theta_b^* \leq \theta_1 < \theta_a^*$. Like the previous case, this cannot be an equilibrium as A can raise a_o by $\varepsilon > 0$ to increase profit.□

Claim 2 *With asymmetric second period pricing policy, for $\theta_1 \in (\frac{1}{3}, \frac{2}{3})$, in any pure strategy equilibrium poaching prices must be lower than past-customer prices.*

Assume that Firm A sets a strictly higher poaching price while Firm B sets a weakly higher past-customer price, i.e., $a_c^* > a_o^*$ and $b_o^* \geq b_c^*$. Then A's switching customers and B's past customers exhibit fairness concerns. The indifferent customer at θ_a and θ_b becomes:

$$r - t\theta_a - a_o = r - t(1-\theta_a) - b_c \tag{A8}$$

$$\theta_a = \frac{1}{2} - \frac{a_o - b_c}{2t} \tag{A9}$$

and

$$r - t\theta_b - a_c - \lambda(a_c - a_o) = r - t(1-\theta_b) - b_o - \lambda(b_o - b_c) \tag{A10}$$

$$\theta_b = \frac{1}{2} - \frac{a_c - b_o}{2t} - \frac{\lambda(a_c - a_o)}{2t} + \frac{\lambda(b_o - b_c)}{2t} \tag{A11}$$

We focus on interior solutions. Firms' profit functions are

$$\Pi_a = a_o\theta_a + a_c(\theta_b - \theta_1) \tag{A12}$$

$$\Pi_b = b_o(1-\theta_b) + b_c(\theta_1 - \theta_a) \tag{A13}$$

First order conditions with respect to prices give that:

$$a_c^*(\theta_1) = \frac{t(2\lambda^2 - 6\lambda\theta_1 + 12\theta_1 - 9)}{3(2\lambda^2 - 3\lambda - 3)} \tag{A14}$$

$$a_o^*(\theta_1) = \frac{t(4\lambda^2 - 6\lambda - 6\theta_1 - 3)}{3(2\lambda^2 - 3\lambda - 3)} \tag{A15}$$

$$b_c^*(\theta_1) = \frac{t(2\lambda^2 + 6\lambda\theta_1 - 6\lambda - 12\theta_1 + 3)}{3(2\lambda^2 - 3\lambda - 3)} \tag{A16}$$

$$b_o^*(\theta_1) = \frac{t(4\lambda^2 - 6\lambda + 6\theta_1 - 9)}{3(2\lambda^2 - 3\lambda - 3)} \tag{A17}$$

For $a_c^*(\theta_1) > a_o^*(\theta_1)$ to be true, we need $\theta_1 < \frac{3-3\lambda+\lambda^2}{3(3-\lambda)}$ which cannot hold for $\theta_1 > \frac{1}{3}$ because $\frac{3-3\lambda+\lambda^2}{3(3-\lambda)} \leq \frac{1}{3}$. By the same logic, if firm B sets a strictly higher poaching price while firm A sets a weakly higher past-customer price, i.e., $b_c^* > b_o^*$ and $a_o^* \geq a_c^*$, then $b_c^*(\theta_1) > b_o^*(\theta_1)$ cannot be true if $\theta_1 < \frac{2}{3}$. Hence, for $\theta_1 \in (\frac{1}{3}, \frac{2}{3})$, the claim holds. □

Claim 3 *Following a symmetric first period equilibrium, there exists a pure strategy second period pricing equilibrium where $a_o^* \geq a_c^*$ and $b_o^* \geq b_c^*$.*

By Claim 1 and Claim 2, the equilibrium, if it exists, must involve both firms charging lower poaching prices. It remains to be shown that such an equilibrium exists. In this case, past customers experience fairness concerns. The marginal consumer at θ_a becomes:

$$r - t\theta_a - a_o - \lambda(a_o - a_c) = r - t(1-\theta_a) - b_c \tag{A18}$$

$$\theta_a = \frac{1}{2} - \frac{a_o - b_c}{2t} - \frac{\lambda(a_o - a_c)}{2t} \tag{A19}$$

Similarly, the marginal consumer at θ_b satisfies:

$$r - t(1-\theta_b) - b_o - \lambda(b_o - b_c) = r - t\theta_b - a_c \tag{A20}$$

$$\theta_b = \frac{1}{2} + \frac{b_o - a_c}{2t} + \frac{\lambda(b_o - b_c)}{2t} \tag{A21}$$

Firms' profit functions in the second period are:

$$\Pi_{a2} = a_o\theta_a + a_c(\theta_b - \theta_1) \tag{A22}$$

$$\Pi_{b2} = b_o(1-\theta_b) + b_c(\theta_1 - \theta_a) \tag{A23}$$

The first order conditions with respect to prices lead to the results in Table 1. The equilibrium prices are:

$$a_c^*(\theta_1) = \left[-\frac{4(1+\lambda)}{3+3\lambda-2\lambda^2}\theta_1 + \frac{9+21\lambda+10\lambda^2-4\lambda^3}{3(1+\lambda)(3+3\lambda-2\lambda^2)}\right]t \tag{A24}$$

$$a_o^*(\theta_1) = \left[\frac{2(1-\lambda)}{3+3\lambda-2\lambda^2}\theta_1 + \frac{3+9\lambda+2\lambda^2-2\lambda^3}{3(1+\lambda)(3+3\lambda-2\lambda^2)}\right]t \tag{A25}$$

$$b_c^*(\theta_1) = \left[\frac{4(1+\lambda)}{3+3\lambda-2\lambda^2}\theta_1 - \frac{3+3\lambda+2\lambda^2+4\lambda^3}{3(1+\lambda)(3+3\lambda-2\lambda^2)}\right]t \tag{A26}$$

$$b_o^*(\theta_1) = \left[-\frac{2(1-\lambda)}{3+3\lambda-2\lambda^2}\theta_1 + \frac{9+9\lambda-4\lambda^2-2\lambda^3}{3(1+\lambda)(3+3\lambda-2\lambda^2)}\right]t \tag{A27}$$

The second order conditions for second period prices hold as $\frac{\partial^2\Pi_{a2}}{\partial a_o^2} = \frac{\partial^2\Pi_{b2}}{\partial b_o^2} = -\left[\frac{\lambda+1}{t}\right] < 0$ and $\frac{\partial^2\Pi_{a2}}{\partial a_c^2} = \frac{\partial^2\Pi_{b2}}{\partial b_c^2} = \frac{-1}{t} < 0$. For $a_o^* \geq a_c^*$ and $b_o^* \geq b_c^*$ to hold, we require that $0 < \theta_1 \in \left(\frac{3+6\lambda+4\lambda^2-\lambda^3}{3(1+\lambda)(3+\lambda)}, \frac{6+6\lambda-\lambda^2+\lambda^3}{3(1+\lambda)(3+\lambda)}\right)$. In this range, we also have $0 < \theta_a < \theta_1 < \theta_b < 1$. For $\lambda \in [0,1]$, this range is symmetric around $\frac{1}{2}$ and non-empty. Hence, this equilibrium exists following a symmetric equilibrium in the first period. □

Proof of Equilibrium Results Presented in Tables 1 and 2

Proof of Claim 2 above shows how we obtain results in Table 1 of the paper. Here we show how we obtain the equilibrium results given in Table 2 of the paper.

The First Period

In the first period, the marginal consumer at θ_1 is indifferent between buying from A at price a_1 and buying from B at price b_1, rationally expecting the second period prices that they will face in the second period. We must have

$$r - t\theta_1 - a_1 + \delta_c\left[r - t(1-\theta_1) - b_c(a_1, b_1)\right] =$$

$$r - t(1-\theta_1) - b_1 + \delta_c\left(r - t\theta_1 - a_c(a_1, b_1)\right) \tag{A28}$$

where $b_c(a_1, b_1)$ and $a_c(a_1, b_1)$ are the consumer's rational expectation of poaching prices in the second period, given the first period prices. Imposing the rational expectations conditions $b_c(a_1, b_1) = b_c^*(\theta_1(a_1, b_1))$ and $a_c(a_1, b_1) = a_c^*(\theta_1(a_1, b_1))$ where $a_c^*(\theta_1(a_1, b_1))$ and $b_c^*(\theta_1(a_1, b_1))$ are the equilibrium poaching prices as a function of θ_1 that are given in the second column of Table 1. It follows that

$$\theta_1 = \frac{1}{2} - \frac{a_1 - b_1}{2t\left(1 + \frac{1+\lambda+2\lambda^2}{3+3\lambda-2\lambda^2}\delta_c\right)} \tag{A29}$$

Firms set first period prices to maximize the total discounted profits over two periods. Hence, the profit functions are

$$\begin{aligned} \Pi_a &= \Pi_{a1} + \delta_f \Pi_{a2}^*(\theta_1) = a_1\theta_1 + \delta_f \Pi_{a2}^*(\theta_1) \\ \Pi_b &= \Pi_{b1} + \delta_f \Pi_{b2}^*(\theta_1) = b_1(1-\theta_1) + \delta_f \Pi_{b2}^*(\theta_1) \end{aligned} \tag{A30}$$

The first order condition solves for the first period prices. We obtain that:

Table 2: Period 1 Price, Period 1 Profits, and Total Discounted Profits

a_1^*	$\frac{3\delta_c(1+2\lambda+3\lambda^2+2\lambda^3)+\delta_f\lambda(7+7\lambda-2\lambda^2)+3(3+6\lambda+\lambda^2-2\lambda^3)}{3(1+\lambda)(3+3\lambda-2\lambda^2)}t$
Π_{a1}^*	$\frac{3\delta_c(1+2\lambda+3\lambda^2+2\lambda^3)+\delta_f\lambda(7+7\lambda-2\lambda^2)+3(3+6\lambda+\lambda^2-2\lambda^3)}{6(1+\lambda)(3+3\lambda-2\lambda^2)}t$
Π_a^*	$\frac{9\delta_c(1+2\lambda+3\lambda^2+2\lambda^3)+\delta_f(15+51\lambda+23\lambda^2-19\lambda^3+2\lambda^4)+9(3+6\lambda+\lambda^2-2\lambda^3)}{18(1+\lambda)(3+3\lambda-2\lambda^2)}t$

The second order condition is satisfied as

$$\frac{\partial^2 \Pi_a}{\partial a_1^2} = \frac{N}{(2\delta_c\lambda^2 - 2\lambda^2 + 3\lambda + \delta_c\lambda + 3 + \delta_c)^2 t} < 0 \tag{A31}$$

where $N = (4\lambda^4 - 4\lambda^3 - 7\lambda^2 - 6\lambda - 3)\delta_c + (5 + 9\lambda + 3\lambda^2 - \lambda^3)\delta_f - 4\lambda^4 + 12\lambda^3 + 3\lambda^2 - 18\lambda - 9$ and the inequality follows since $\lambda \leq 1$. $\square$

Proof of Proposition 1

We analyze the impact of λ on second period prices. Since firms are symmetric, we analyze the impact from firm A's perspective. The equilibrium second period prices are given in the last column of Table 1. Taking the partial derivative with respect to λ, we have

$$\frac{\partial a_o^*}{\partial \lambda} = -\frac{t}{3(1+\lambda)^2} < 0 \tag{A32}$$

$$\frac{\partial a_c^*}{\partial \lambda} = \frac{t}{3(1+\lambda)^2} > 0 \tag{A33}$$

Hence, as λ increases, the prices charged to past customers decrease and the poaching prices increase, by the same magnitude. From A's perspective, the segment of switchers is in the range $[\theta_a^*, \theta_1^*]$ as in equilibrium, $\theta_1^* = \frac{1}{2}$. $\theta_a^* = \frac{2+\lambda}{6}$. Hence, as λ increases, θ_a^* increases and fewer consumers switch. $\square$

Proof of Proposition 2

In equilibrium, the second period profits are $\Pi_{a2}^* = \frac{5+5\lambda-\lambda^2}{18(1+\lambda)}t$ as shown in the second column of Table 1. Partial derivative with respect to λ gives that

$$\frac{\partial \Pi_{a2}^*}{\partial \lambda} = -\frac{\lambda(\lambda+2)t}{18(\lambda+1)^2} < 0 \tag{A34}$$

Hence, a higher λ leads to lower second period profits. $\square$

Proof of Proposition 3

In the symmetric equilibrium, two firms split the market equally. Hence, sales are fixed and profits increase as a result of an increase in prices. We show that first period prices increase with λ. The equilibrium first period prices are given in Table 2. Partial derivative with respect to λ gives that

$$\frac{\partial a_1^*}{\partial \lambda} = \frac{24\delta_c\lambda(2+5\lambda+4\lambda^2+\lambda^3)+\delta_f(21+42\lambda+17\lambda^2+4\lambda^3+12\lambda^4)}{3(1+\lambda)^2(2\lambda^2-3\lambda-3)^2}t > 0 \quad \text{(A35)}$$

Hence first period prices increase with λ. Consequently, first period profits also increase with λ. $\square$

Proof of Proposition 4

Without customer recognition, the total discounted profits over two periods are given in Lemma 1. Let Π_n^* denote the total discounted profits with no recognition.

$$\Pi_n^* = \frac{(1+\delta_f)t}{2} \quad \text{(A36)}$$

With customer recognition, the total discounted profits over two periods are given in Table 2. Let Π_r^* denote the total discounted profits with recognition.

$$\Pi_r^* = \frac{Nt}{18(1+\lambda)(3+3\lambda-2\lambda^2)} \quad \text{(A37)}$$

where $N = 9\delta_c(1+2\lambda+3\lambda^2+2\lambda^3)+\delta_f(15+51\lambda+23\lambda^2-19\lambda^3+2\lambda^4)+9(3+6\lambda+\lambda^2-2\lambda^3)$. Comparing these two profits, we have

$$\Pi_r^* - \Pi_n^* = \frac{9\delta_c(1+2\lambda+3\lambda^2+2\lambda^3)-\delta_f(12+3\lambda-14\lambda^2+\lambda^3-2\lambda^4)}{18(1+\lambda)(3+3\lambda-2\lambda^2)}t \quad \text{(A38)}$$

which is positive if $\frac{9(1+2\lambda+3\lambda^2+2\lambda^3)}{12+3\lambda-14\lambda^2+\lambda^3-2\lambda^4} > \frac{\delta_f}{\delta_c}$. As λ increases from 0 to 1, $\frac{9(1+2\lambda+3\lambda^2+2\lambda^3)}{12+3\lambda-14\lambda^2+\lambda^3-2\lambda^4}$ increases from $\frac{3}{4}$ to infinity. When $\delta_f = \delta_c$, this condition is satisfied for $\lambda > \underline{\lambda} \approx 0.14$. When $\delta_f \neq \delta_c$, this condition holds as long as $\lambda > \underline{\lambda}$ where λ is such that $\frac{9(1+2\underline{\lambda}+3\underline{\lambda}^2+2\underline{\lambda}^3)}{12+3\underline{\lambda}-14\underline{\lambda}^2+\underline{\lambda}^3-2\underline{\lambda}^4} = \frac{\delta_f}{\delta_c}$. $\square$

Proof of Proposition 5

Here we prove that consumer surplus decreases with λ. Let CS denote the consumer surplus derived based on the monetary payoff only, and CS^f denote the consumer surplus that also includes the fairness components. By symmetry, we have the following.

$$\begin{aligned} CS &= 2\int_0^{\theta_a^*}[r-\theta-a_1^*+\delta_c(r-\theta-a_o^*)]\,\mathrm{d}\theta \\ &+ 2\int_{\theta_a^*}^{\theta_1^*}\{r-\theta-a_1^*+\delta_c[r-(1-\theta)-b_c^*]\}\,\mathrm{d}\theta \\ &= \frac{N_1}{36(1+\lambda)(3+3\lambda-2\lambda^2)} \end{aligned} \tag{A39}$$

where $N_1 = (4\lambda^5+36r\lambda^2+216r\lambda-246\lambda-18\lambda^4-6\lambda^3+108r-129-72r\lambda^3-109\lambda^2)\delta_c+(24\lambda^3-84\lambda^2-84\lambda)\delta_f+90\lambda^3-270\lambda+108r+216r\lambda-45\lambda^2-72r\lambda^3-135+36r\lambda^2$. As λ increases, CS is impacted as follows.

$$\frac{\partial CS}{\partial\lambda} = -\frac{N_2\delta_f-N_3\delta_c}{9(1+\lambda)^2(2\lambda^2-3\lambda-3)^2} \tag{A40}$$

where $N_2 = 63+126\lambda+51\lambda^2+12\lambda^3+36\lambda^4>0$ and $N_3 = 9-99\lambda-309\lambda^2-318\lambda^3-122\lambda^4+15\lambda^5+12\lambda^6-4\lambda^7$. N_3 is monotonically decreasing in λ and becomes negative for $\lambda>\lambda_1\approx 0.07$. When N_3 is negative, $\frac{\partial CS}{\partial\lambda}<0$. Even when N_3 is positive, $\frac{\partial CS}{\partial\lambda}<0$ if $\frac{\delta_f}{\delta_c}>\frac{N_3}{N_2}$. $\frac{N_3}{N_2}$ is monotonically decreasing from $\frac{1}{7}$ as λ increases. Hence, as long as $\frac{\delta_f}{\delta_c}>\frac{1}{7}$, consumer surplus is decreasing in λ. This condition is always satisfied when $\delta_f\geq\delta_c$, i.e., firms are weakly more patient than consumers.

The consumer surplus including the fairness component is:

$$CS^f = CS-2\int_0^{\theta_a^*}\delta_c\lambda(a_o^*-a_c^*)\,\mathrm{d}\theta = -\frac{N_4}{36(1+\lambda)(3+3\lambda-2\lambda^2)} \tag{A41}$$

where $N_4 = (4\lambda^5 - 36r\lambda^2 + 270\lambda - 216r\lambda + 14\lambda^4 - 34\lambda^3 - 108r + 129 + 72r\lambda^3 + 121\lambda^2)\delta_c + (84\lambda + 84\lambda^2 - 24\lambda^3)\delta_f - 90\lambda^3 + 270\lambda - 108r - 216r\lambda + 45\lambda^2 + 72r\lambda^3 + 135 - 36r\lambda^2$.

$$\frac{\partial CS^f}{\partial \lambda} = -\frac{N_5\delta_c + N_6\delta_f}{9(1+\lambda)^2(2\lambda^2 - 3\lambda - 3)^2} \tag{A42}$$

where $N_5 = 9 + 117\lambda + 231\lambda^2 + 210\lambda^3 + 130\lambda^4 + 31\lambda^5 - 4\lambda^6 - 4\lambda^7 > 0$ and $N_6 = 63 + 126\lambda + 51\lambda^2 + 12\lambda^3 + 36\lambda^4 > 0$. Hence, $\frac{\partial CS^f}{\partial \lambda} < 0$. Therefore, consumer surplus decreases with λ. $\square$

Proof of Proposition 6

Let SW and SW^f denote the social welfare derived excluding and including the fairness component respectively.

$$\begin{aligned} SW &= 2\int_0^{\theta_a^*} (1+\delta_c)(r-\theta) + a_o(\delta_f - \delta_c)\,\mathrm{d}\theta \\ &+ 2\int_{\theta_a^*}^{\theta_1^*} r - \theta + \delta_c[r - (1-\theta)] + b_c(\delta_f - \delta_c)\,\mathrm{d}\theta \end{aligned} \tag{A43}$$

SW changes with λ as follows.

$$\frac{\partial SW}{\partial \lambda} = \frac{(1 + 3\lambda - \lambda^3)\delta_c - \delta_f\lambda(\lambda+2)}{9(1+\lambda)^2} \tag{A44}$$

which is weakly positive if $\frac{\delta_c}{\delta_f} \geq \frac{\lambda(\lambda+2)}{1+3\lambda-\lambda^3}$. The term on the right hand side ranges between $[0,1]$. If $\delta_c = \delta_f$, the condition is always satisfied.

If we were to include the fairness component, the social welfare is

$$SW^f = SW - 2\int_0^{\theta_a^*} \lambda(a_o^* - a_c^*)\,\mathrm{d}\theta = SW - 2\lambda(a_o^* - a_c^*)\theta_a^* \tag{A45}$$

SW^f changes with λ as follows.

$$\frac{\partial SW^f}{\partial \lambda} = \frac{(\lambda^3 + 4\lambda^2 + 5\lambda - 1)\delta_c - \delta_f\lambda(\lambda+2)}{9(1+\lambda)^2} \tag{A46}$$

$\lambda^3 + 4\lambda^2 + 5\lambda - 1 > 0$ if $\lambda > \lambda_2 \approx 0.17$. In this case, $\frac{\partial SW^f}{\partial \lambda} \geq 0$ if and only if $\frac{\delta_c}{\delta_f} \geq \frac{\lambda(\lambda+2)}{\lambda^3+4\lambda^2+5\lambda-1}$. If $\delta_c \leq \delta_f$, then $\frac{\delta_c}{\delta_f} \leq 1$. $\frac{\lambda(\lambda+2)}{\lambda^3+4\lambda^2+5\lambda-1} \leq 1$ if $\lambda > \hat{\lambda} \approx 0.26$. Hence, $\frac{\partial SW^f}{\partial \lambda} \geq 0$ if $\lambda > \hat{\lambda} \approx 0.26$ and $\frac{\delta_c}{\delta_f} \geq \frac{\lambda(\lambda+2)}{\lambda^3+4\lambda^2+5\lambda-1}$, where the second condition always holds if $\delta_c = \delta_f$.

□

APPENDIX B

PROOFS FOR CHAPTER 2

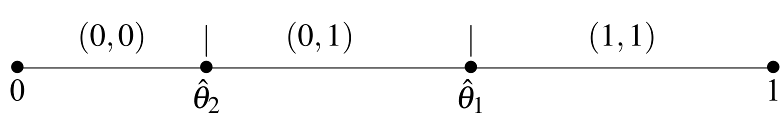
Benchmark Case:

We solve for the equilibrium outcome in the benchmark case where consumer preferences are context-independent.

The Firm Does Not Introduces Upgrades

If the firm does not introduce upgrades, it sells the base product over two periods. In this case, each consumer has three options. First, the consumer can buy the base product in period 1 at $\hat{p}_1$ and use it for two periods. We denote this option by $(1,1)$. Second, the consumer can wait to buy the base product in period 2 at $\hat{p}_2$ and use it for one period only. We denote this option by $(0,1)$. Alternatively, the consumer can refrain from buying any products. We denote this option by $(0,0)$. The pattern that reflects these three decisions is shown in Figure A1. In this pattern, consumers with higher valuations consume more quality over two periods. We solve for consumers' and the firm's decisions in period 2 first.

Figure A1: Consumer Choice Pattern When There are No Upgrades



Period 2. In period 2, consumers and the firm observe the sales volume in period 1, that is $1-\hat{\theta}_1$. Obviously, the consumer who has bought the base product in period 1 will not

purchase it again. These are the consumers whose $\theta > \hat{\theta}_1$. The consumer in the region $\theta < \hat{\theta}_1$ did not buy the base product in period 1. He would buy the product in the second period if the utility of buying and consuming it in one period is positive, when the following is true.

$$\theta - \hat{p}_2 > 0$$

$$\theta > \hat{p}_2 = \hat{\theta}_2 \tag{B1}$$

The firm's profit function in period 2 is:

$$\hat{\Pi}_2 = \hat{p}_2(\hat{\theta}_1 - \hat{\theta}_2) \tag{B2}$$

First order condition with respect to $\hat{p}_2$ gives that:

$$\hat{p}_2^* = \frac{\hat{\theta}_1}{2} \tag{B3}$$

Period 1. In period 1, consumers decide whether to buy the product now or not. The consumer prefers buying the product in period 1 over waiting to buy it in period 2 if the following is true:

$$2\theta - \hat{p}_1 > \theta - \hat{p}_2$$

$$\theta > \frac{2\hat{p}_1}{3} = \hat{\theta}_1 \tag{B4}$$

The firm in period 1 sets $\hat{p}_1$ to maximize its total profit from selling the base product in two periods. The profit function is

$$\hat{\Pi}_1 = \hat{p}_1(1 - \hat{\theta}_1) + \hat{p}_2^*(\hat{\theta}_1 - \hat{\theta}_2) \tag{B5}$$

The first order condition with respect to $\hat{p}_1$ gives that:

$$\hat{p}_1^* = \frac{9}{10} \tag{B6}$$

In equilibrium, $\hat{\Pi}_1^* = \frac{9}{20}$, $\hat{\Pi}_2^* = \frac{9}{100}$, $\hat{p}_1^* = \frac{9}{10}$, and $\hat{p}_2^* = \frac{3}{10}$. $\hat{\theta}_1^* = \frac{3}{5}$ and $\hat{\theta}_2^* = \frac{3}{10}$. The equilibrium volume sale is $\frac{2}{5}$ in period 1 and $\frac{3}{10}$ in period 2.

In the next section we will examine if the firm can achieve a higher profit by selling an upgraded product in period 2.

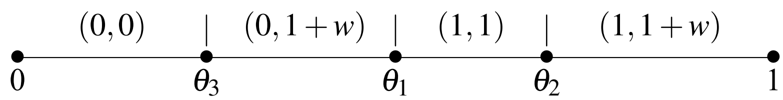
The Firm Introduces Upgrades

Now consider that the firm introduces an upgraded product to replace its base product in period 2. When the firm introduces the upgrade, the firm sells the base product in period 1 and the upgraded product in period 2. Four consumer segments can arise. First, a consumer can buy both the base product and the upgraded product. The consumption utility of this choice is $\theta(2+w)-p_1-p_2$. Second, the consumer can buy the base product to use in two periods and refrain from buying the upgraded product. The corresponding consumption utility is $2\theta - p_1$. Third, the consumer can forgo purchase of the base product and wait to buy the upgraded product. The utility of this choice is $\theta(1+w)-p_2$. Fourth, the consumer can choose to buy nothing and forego consumption completely. Obviously, doing so, the consumer receives zero consumption utility. We again solve for the equilibrium outcome backward.

Case A: $p_2 \leq w$**.**

We first consider that all four consumer choices can arise. The firm sells the upgrade to both new and existing consumers in period 2. The consumption pattern is shown as follows.

Figure A2: Consumer Choice Pattern A When the Firm Introduces Upgrades



Period 2. In the beginning of period 2, θ_1, i.e, the consumer who is indifferent between buying the base product and waiting to buy the upgrade, has been observed. The consumer whose $\theta > \theta_1$ has bought the base product in period 1. He prefers to buy the upgraded product rather than using the base product in period 2 if the following is true.

$$\begin{aligned} \theta(1+w) - p_2 &> \theta \\ \theta &> \frac{p_2}{w} = \theta_2 \end{aligned} \tag{B7}$$

The consumer whose $\theta < \theta_1$ has not purchased the base product. He prefers to buy the upgraded product rather than using nothing in period 2, if the following holds.

$$\begin{aligned} \theta(1+w) - p_2 &> 0 \\ \theta &> \frac{p_2}{1+w} = \theta_3 \end{aligned} \tag{B8}$$

In Case A, the firm can sell the upgraded product to existing consumers in $(\theta_2, 1)$ and new consumers in (θ_3, θ_1). This pattern occurs if $\theta_2 \leq 1$ which reduces to $p_2 \leq w$. In this case, the firm's profit function in period 2 is

$$\Pi_2^a = p_2^a(1 - \theta_2 + \theta_1 - \theta_3) - c \tag{B9}$$

The firm in period 2 sets p_2^a to maximize the period 2 profit. The first order condition gives

$$p_2^{a*} = \frac{w(1+w)}{2(1+2w)}(1+\theta_1) \tag{B10}$$

At this price, the profit in period 2 is $\Pi_2^{a*} = \frac{w(1+w)(1+\theta_1)^2}{4(1+2w)}$.

Period 1. In period 1, the consumer would rather buy the base product to use over two periods rather than to wait for the upgraded product, if the following is true.

$$\begin{aligned} 2\theta - p_1^a &> \theta(1+w) - p_2^a \\ \theta &> \frac{w^2 + w - 2p_1^a(1+2w)}{3w^2 - 3w - 2} = \theta_1^a \end{aligned} \tag{B11}$$

The firm's overall profit from selling two products is

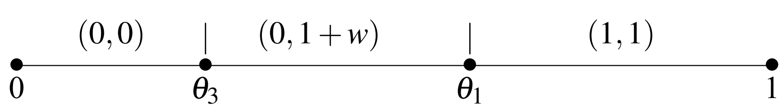
$$\Pi_1 = p_1^a(1-\theta_1^a) + p_2^a(1-\theta_2^a+\theta_1^a-\theta_3^a) - c \tag{B12}$$

The first order condition with respect to p_1^a gives the equilibrium outcome as follows. $p_1^{a*} = -\frac{w^4-10w^3+3w^2+8w+2}{(1+2w)(7w^2-5w-4)}$, $p_2^{a*} = \frac{(5w^2-4w-3)w(1+w)}{(1+2w)(7w^2-5w-4)}$, $\theta_1^{a*} = \frac{3w^2-3w-2}{7w^2-5w-4}$, $\theta_2^{a*} = \frac{(5w^2-4w-3)(1+w)}{(1+2w)(7w^2-5w-4)}$, $\theta_3^{a*} = \frac{(5w^2-4w-3)w}{(1+2w)(7w^2-5w-4)}$, $\Pi_1^{a*} = \frac{3w^4+6w^3-6w^2-6w-1}{(1+2w)(7w^2-5w-4)} - c$, $\Pi_2^{a*} = \frac{(5w^2-4w-3)^2(1+w)w}{(1+2w)(7w^2-5w-4)^2} - c$. We can verify that $p_1^{a*} > p_2^{a*} > 0$, and $1 > \theta_2^{a*} > \theta_1^{a*} > \theta_3^{a*} > 0$.

Case B: $p_2 > w$.

Period 2. Alternatively, the firm can raise p_2 in period 2 such that $\theta_2 > 1$, i.e., $p_2 > w$. In this case, the consumption pattern is shown below.

Figure A3: Consumer Choice Pattern B When the Firm Introduces Upgrades



For this case, the profit function in period 2 is

$$\Pi_2^b = p_2^b(\theta_1^b - \theta_3^b) - c \tag{B13}$$

The first order condition gives

$$p_2^{b*} = \frac{1+w}{2}\theta_1^b \tag{B14}$$

At this p_2^{b*}, the resulting profit in period 2 is $\Pi_2^{b*} = \frac{1+w}{4}\theta_1^2$. Suppose θ_1^b is fixed. $\Pi_2^{a*} > \Pi_2^{b*}$ if and only if $\theta_1^b < \frac{w+\sqrt{2w^2+w}}{1+w} = \bar{\theta}_1$. $\bar{\theta}_1$ ranges from $(0,1)$ for $w \in (0, \frac{1}{2})$ and is increasing in w. Therefore, as w increases, it is more likely that $\Pi_2^{a*} > \Pi_2^{b*}$ for Case A to apply. As w decreases, it is more likely that $\Pi_2^{a*} < \Pi_2^{b*}$ and Case B applies.

Period 1. Suppose Case B applies. In period 1, the consumer would rather buy the base product to use over two periods rather than to wait for the upgraded product, if the following is true.

$$\begin{aligned} 2\theta - p_1^b &> \theta(1+w) - p_2^b \\ \theta &> \frac{2p_1^b}{3-w} = \theta_1^b \end{aligned} \tag{B15}$$

The firm's overall profit from selling two products is

$$\Pi_1^b = p_1^b(1-\theta_1^b) + p_2^{b*}(\theta_1^b - \theta_3^b) - c \tag{B16}$$

The first order condition with respect to p_1^b gives the equilibrium outcome as follows. $p_1^{b*} = \frac{(3-w)^2}{2(5-3w)}$, $p_2^{b*} = \frac{(1+w)(3-w)}{2(5-3w)}$, $\theta_1^{b*} = \frac{3-w}{5-3w}$, $\theta_2^{b*} = \frac{(3-w)(1+w)}{2w(5-3w)}$, $\theta_3^{b*} = \frac{3-w}{2(5-3w)}$, $\Pi_1^{b*} = \frac{(3-w)^2}{4(5-3w)} - c$, $\Pi_2^{b*} = \frac{(3-w)^2(1+w)}{4(5-3w)^2} - c$. We can verify that $p_1^{b*} > p_2^{b*} > 0$, and $\theta_2^{b*} > 1 > \theta_1^{b*} > \theta_3^{b*} > 0$.

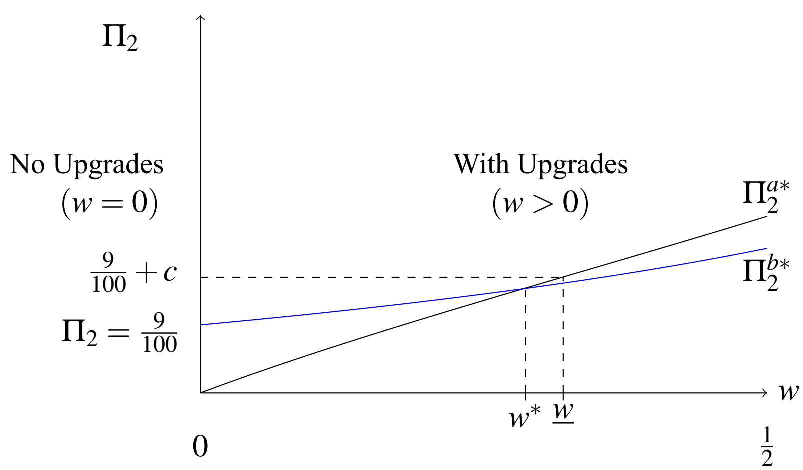
Lemma 3 *Suppose context-dependent preferences do not exist and the firm introduces an upgrade. There exists a $w^* \in (0, \frac{1}{2})$ such that for $w \in (0, w^*)$ Case B applies and for $w \in$*

$(w^*, \frac{1}{2})$ *Case A applies.*

The firm sets p_2 to maximize profit in period 2. We compare the profits obtained from Cases A and B. $\Pi_2^{a*} = \frac{(5w^2-4w-3)^2(1+w)w}{(1+2w)(7w^2-5w-4)^2} - c$. $\Pi_2^{b*} = \frac{(3-w)^2(1+w)}{4(5-3w)^2} - c$. $\Pi_2^{b*} - \Pi_2^{a*} = \frac{(1+w)(1478w^4+2546w^3-1295w^2-348w+144-5500w^5+3761w^6-802w^7)}{4(5-3w)^2(1+2w)(7w^2-5w-4)^2}$ which is positive for $w = 0$, negative for $w = \frac{1}{2}$ and is decreasing in w. Therefore, there exists a $w^* \in (0, \frac{1}{2})$ such that at w^*, $\Pi_2^{b*} - \Pi_2^{a*} = 0$. For $w \in (0, w^*)$, $\Pi_2^{b*} - \Pi_2^{a*} > 0$ so Case B applies. For $w \in (w^*, \frac{1}{2})$, $\Pi_2^{b*} - \Pi_2^{a*} < 0$ so Case A applies. □

We depict the operating case and profit in period 2 in the figure below.

Figure A4: Period 2 Profit Varies with w



Proof of Proposition 1:

We first show that the period 2 profit from selling the upgraded product is increasing in w.

If Case A applies, the profit is given in Equation B9.

$$\begin{aligned}\frac{d\Pi_2^{*a}}{dw} &= p_2^{a*}\left(-\frac{\partial\theta_2^{a*}}{\partial w}+\frac{d\theta_1^{a*}}{dw}-\frac{\partial\theta_3^{a*}}{\partial w}\right)\\ &= p_2^{a*}\left(\frac{p_2^{a*}}{w^2}+\left(\frac{\partial\theta_1^{a*}}{\partial w}+\frac{\partial\theta_1^{a*}}{\partial p_1^{a*}}\frac{\partial p_1^{a*}}{\partial w}\right)+\frac{p_2^{a*}}{(1+w)^2}\right)\end{aligned} \tag{B17}$$

Obviously $\frac{p_2^{a*}}{w^2}>0$ and $\frac{p_2^{a*}}{(1+w)^2}>0$. $\frac{\partial\theta_1^{a*}}{\partial w}=\frac{2(-3w^2-2w-1+6p_1^{a*}w^2+6p_1^{a*}w+p_1^{a*})}{(3w^2-3w-2)^2}=-\frac{2(2w^4-2w^3-8w^2-w+1)}{(3w^2-3w-2)(1+2w)(7w^2-5w-4)}$, whose sign is ambiguous. $\frac{\partial\theta_1^{a*}}{\partial p_1^{a*}}=-\frac{2(1+2w)}{3w^3-3w-2}>0$ for $w\in(0,\frac{1}{2})$. $\frac{\partial p_1^{a*}}{\partial w}=-\frac{-6w^5-51w^4+20w^3+14w^6+21w^2-12w-6}{(1+2w)^2(7w^2-5w-4)^2}>0$ for $w\in(0,\frac{1}{2})$. Overall, for $w\in(0,\frac{1}{2})$, $\frac{\partial\theta_1^{*}}{\partial w}+\frac{\partial\theta_1^{a*}}{\partial p_1^{a*}}\frac{\partial p_1^{a*}}{\partial w}>0$. Therefore, $\frac{\partial\Pi_2^{a*}}{\partial w}>0$.

If Case B applies, the profit is given in Equation B13.

$$\frac{d\Pi_2^{*b}}{dw}=p_2^{b*}\left(\frac{d\theta_1^{b*}}{dw}-\frac{\partial\theta_3^{b*}}{\partial w}\right)=p_2^{b*}\left(\frac{\partial\theta_1^{b*}}{\partial w}+\frac{\partial\theta_1^{b*}}{\partial p_1^{b*}}\frac{\partial p_1^{b*}}{\partial w}+\frac{p_2^{b*}}{(1+w)^2}\right) \tag{B18}$$

$\frac{\partial\theta_1^{b*}}{\partial w}>0$, $\frac{\partial\theta_1^{b*}}{\partial p_1^{b*}}>0$, and $\frac{p_2^{b*}}{(1+w)^2}>0$. The sign of $\frac{\partial p_1^{b*}}{\partial w}$ is ambiguous. Overall, $\frac{d\Pi_2^{*b}}{dw}>0$. Profit is increasing in w.

We discussed in Lemma 3 that Case B applies for $w\in(0,w^*)$ and when $w=0$, $\Pi_2^{b*}=\frac{9}{100}-c$. For $w\in(w^*,\frac{1}{2})$, Case A applies and when $w=\frac{1}{2}$, $\Pi_2^{a*}=\frac{675}{2888}-c\doteq 0.23-c$. We have shown that the firm can obtain the profit of $\frac{9}{100}$ in period 2 if it does not introduce the upgrade. Therefore, as long as $\frac{675}{2888}-c>\frac{9}{100}$, i.e., $c<\frac{675}{2888}-\frac{9}{100}\doteq 0.14=c_{max}$, then there exists a $\underline{w}$ such that at $\underline{w}$, the firm is indifferent between introducing the upgrade and not introducing it. Since the profit of introducing the upgrade is increasing in w, the firm introduces the upgrade if any only $w>\underline{w}$. □

Proof of Proposition 2:

We prove Proposition 2 by showing two results: period 2 profit under context-dependent preferences is increasing in w; context-dependent preferences increase (decreases) the period 2 profit if and only if $w < \hat{w}$ ($w > \hat{w}$). Define the cost for introducing the upgrade with $w = \hat{w}$ to break even as $\hat{c}$. It follows that the firm introduces upgrades in a larger (smaller) range of situations if and only if $c < \hat{c}$ ($c > \hat{c}$).

Lemma 4 *Under context-dependent preferences, the period 2 profit is increasing in w.*

As in the base model, we solve for the equilibrium outcome backwards.

Period 2. In period 2, the reference price is $\frac{p_2}{2}$, where p_2 is the price of the upgraded product. The reference quality is $\frac{2+w}{3}$. The consumer at θ_2 chooses between buying the upgraded product and using the base product in period 2. Buying the upgraded product induces a gain in quality and a loss in price. Using the base product induces a smaller gain in quality and a gain in price as the consumer can receive some quality but does not need to pay again. The consumer prefers to purchase the upgraded product rather than consuming the base product if

$$\begin{aligned} \theta(1+w) - p_2 + \theta\left(1 + w - \frac{2+w}{3}\right) - \lambda\frac{p_2}{2} &> \theta + \theta\left(1 - \frac{2+w}{3}\right) + \frac{p_2}{2} \\ \theta &> \frac{3+\lambda}{4w}p_2 = \theta_2 \qquad \text{(B19)} \end{aligned}$$

The consumer who has not purchased the base product would buy the upgraded product if

$$\begin{aligned}\theta(1+w)-p_2+\theta\left(1+w-\frac{2+w}{3}\right)-\lambda\frac{p_2}{2} &= -\lambda\theta\frac{2+w}{3}+\frac{p_2}{2}\\ \theta &= \frac{3(3+\lambda)}{2(4+5w+2\lambda+w\lambda)}p_2=\theta_3\end{aligned} \tag{B20}$$

Case A: Period 2 profit is increasing in w.

The firm sets p_2 to maximize the period 2 profit. If Case A applies (see Figure A2), the profit function in period 2 is

$$\Pi_2 = p_2(1-\theta_2+\theta_1-\theta_3)-c \tag{B21}$$

The first order condition gives that

$$p_2^* = \frac{2w(4+5w+2\lambda+w\lambda)}{(3+\lambda)(4+11w+2\lambda+w\lambda)}(1+\theta_1) \tag{B22}$$

Period 1. In period 1, the consumer would rather buy the base product to use over two periods rather than to wait for the upgraded product, if the following is true.

$$\begin{aligned}&2\theta-p_1+\frac{\theta}{2}-\lambda\frac{p_1}{2}+\theta\left(1-\frac{2+w}{3}\right)+\frac{p_2}{2}\\ &>\theta(1+w)-p_2-\lambda\frac{\theta}{2}+\frac{p_1}{2}+\theta\left(1+w-\frac{2+w}{3}\right)-\lambda\frac{p_2}{2}\\ &\theta>\frac{(3+\lambda)(p_1-p_2)}{3-4w+\lambda}=\theta_1\end{aligned} \tag{B23}$$

The firm's overall profit from selling two products is

$$\Pi_1 = p_1(1-\theta_1)+p_2^*(1-\theta_2+\theta_1-\theta_3)-c \tag{B24}$$

The first order condition gives the equilibrium solution $p_1^* = \frac{U_1}{2(\lambda+3)(2\lambda+w\lambda+4+11w)D_1}$,*
$p_2^* = \frac{U_2 w(2\lambda+w\lambda+4+5w)}{(\lambda+3)(2\lambda+w\lambda+4+11w)D_1}$,† $\Pi_1^* = \frac{U_3}{4(\lambda+3)(2\lambda+w\lambda+4+11w)D_1} - c$,‡ and $\Pi_2^* = \frac{U_2^2 w(2\lambda+\lambda w+4+5w)}{4(\lambda+3)(2\lambda+w\lambda+4+11w)D_1^2} - c$. As w increases, the change in period 2 profit is given by

$$\begin{aligned}\frac{d\Pi_2^*}{dw} &= p_2^*\left(-\frac{\partial\theta_2^*}{\partial w}+\frac{d\theta_1^*}{dw}-\frac{\partial\theta_3^*}{\partial w}\right)\\ &= p_2^*\left(\frac{(\lambda+3)p_2^*}{4w^2}+\frac{\partial\theta_1^*}{\partial w}+\frac{\partial\theta_1^*}{\partial p_1^*}\frac{\partial p_1^*}{\partial w}+\frac{3(\lambda+3)(\lambda+5)p_2^*}{2(2\lambda+\lambda w+4+5w)^2}\right) \qquad \text{(B25)}\end{aligned}$$

where θ_2, θ_3, and θ_1 are given in Equations B19, B20, and B23 respectively. We can verify that $\frac{d\theta_1^*}{dw} > 0$. Hence, $\frac{d\Pi_2^*}{dw} > 0$.

Case B: Period 2 profit is increasing in w.

If Case B applies (see Figure A3), the profit function in period 2 is

$$\Pi_2 = p_2(\theta_1 - \theta_3) - c \qquad \text{(B26)}$$

The first order condition gives that

$$p_2^* = \frac{4+5w+2\lambda+w\lambda}{3(3+\lambda)}\theta_1 \qquad \text{(B27)}$$

---

*$U_1 = 4\lambda^4 + 4\lambda^4 w + \lambda^4 w^2 + 28\lambda^3 w^2 + 76\lambda^3 w + 40\lambda^3 + 134\lambda^2 w^2 + 148\lambda^2 + 436\lambda^2 w - 8w^4\lambda^2 - 80\lambda^2 w^3 - 896\lambda w^3 + 996\lambda w + 316\lambda w^2 - 80w^4\lambda + 240\lambda + 792w + 144 + 385w^2 - 1904w^3 + 376w^4$ and $D_1 = 2\lambda^2 + w\lambda^2 - 3\lambda w^2 + 8\lambda w + 10\lambda - 39w^2 + 21w + 12$.

†$U_2 = 3\lambda^2 w + 6\lambda^2 - 8\lambda w^2 + 26\lambda w + 30\lambda - 112w^2 + 67w + 36$.

‡$U_3 = 4\lambda^4 + 4\lambda^4 w + \lambda^4 w^2 + 8\lambda^3 w^3 + 60\lambda^3 w^2 + 108\lambda^3 w + 40\lambda^3 - 32w^4\lambda^2 - 24\lambda^2 w^3 + 454\lambda^2 w^2 + 660\lambda^2 w + 148\lambda^2 - 512w^4\lambda - 1128\lambda w^3 + 1404\lambda w^2 + 1508\lambda w + 240\lambda - 1184w^4 - 2312w^3 + 1537w^2 + 1176w + 144$.

Period 1. In period 1, the consumer would rather buy the base product to use over two periods rather than to wait for the upgraded product, if the following is true.

$$2\theta - p_1 + \frac{\theta}{2} - \lambda\frac{p_1}{2} + \theta\left(1 - \frac{2+w}{3}\right) + \frac{p_2}{2}$$
$$> \theta(1+w) - p_2 - \lambda\frac{\theta}{2} + \frac{p_1}{2} + \theta\left(1 + w - \frac{2+w}{3}\right) - \lambda\frac{p_2}{2}$$
$$\theta > \frac{2p_1}{3-w} = \theta_1 \tag{B28}$$

The firm's overall revenue from selling two products is

$$\Pi_1 = p_1(1-\theta_1) + p_2(\theta_1 - \theta_3) - c \tag{B29}$$

The first order condition gives the equilibrium solution as follows. $p_1^* = \frac{(5\lambda+w\lambda+13-7w)^2}{3(\lambda+3)(8\lambda+w\lambda+22-19w)}$, $p_2^* = \frac{(5\lambda+w\lambda+13-7w)(2\lambda+w\lambda+4+5w)}{3(\lambda+3)(8\lambda+w\lambda+22-19w)}$, $\Pi_1^* = \frac{(5\lambda+w\lambda+13-7w)^2}{6(\lambda+3)(8\lambda+w\lambda+22-19w)} - c$, $\Pi_2^* = \frac{(5\lambda+w\lambda+13-7w)^2(2\lambda+w\lambda+4+5w)}{6(\lambda+3)(8\lambda+w\lambda+22-19w)^2} - c$, $\theta_1^* = \frac{5\lambda+w\lambda+13-7w}{8\lambda+w\lambda+22-19w}$, $\theta_2^* = \frac{(5\lambda+w\lambda+13-7w)(2\lambda+w\lambda+4+5w)}{12w(8\lambda+w\lambda+22-19w)}$, and $\theta_3^* = \frac{5\lambda+w\lambda+13-7w}{2(8\lambda+w\lambda+22-19w)}$. The profit of selling an upgrade is given in Equation B26. As w increases, the change in this profit is given by

$$\frac{d\Pi_2^*}{dw} = p_2^*\left(\frac{d\theta_1^*}{dw} - \frac{\partial\theta_3^*}{\partial w}\right) = p_2^*\left(\frac{3(\lambda^2+16\lambda+31)}{(8\lambda+\lambda w+22-19w)^2} + \frac{3(\lambda+3)(\lambda+5)p_2^*}{2(2\lambda+\lambda w+4+5w)^2}\right) \tag{B30}$$

where θ_3^*, and θ_1^* are given in Equations B20 and B28. $\frac{3(\lambda^2+16\lambda+31)}{(8\lambda+\lambda w+22-19w)^2} + \frac{3(\lambda+3)(\lambda+5)p_2^*}{2(2\lambda+\lambda w+4+5w)^2} > 0$, hence $\frac{d\Pi_2^*}{dw} > 0$.

Lemma 5 *There exists a positive $\hat{c}$ such that context-dependent preferences increase (decrease) the period 2 profit if $c < \hat{c}$ ($c > \hat{c}$).*

Lemma 3 has shown that without context-dependent preferences, $\Pi_2^{b*} = \Pi_2^{a*}$ at $w = w^*$. We denote the profit that applies without context-dependent preferences by Π_2^{n*} (see Figure A5). We show that with context-dependent preferences, the profit in Case B increases while the profit in Case A decreases, which implies that Case B applies in a larger range of situations under context-dependent preferences. Hence, there exists a $w^{r*} > w^*$ such that the period 2 profit in Cases A exceeds that in Case B if and only if $w > w^{r*}$.

It is useful to recall that context-dependent preferences exist as long as the loss aversion parameter $\lambda > 1$. If $\lambda = 1$, then the model reduces to that preferences are independent of context. In this way, the impact of context-dependent preferences is equivalent to the impact of an increase in λ where $\lambda \geq 1$.

Case A: Context-dependent preferences decrease period 2 profit.

The profit of selling an upgrade is given in Equation B21. As λ increases, the change in this profit is given by

$$\begin{aligned} \frac{d\Pi_2^*}{d\lambda} &= p_2^*\left(-\frac{\partial\theta_2^*}{\partial\lambda}+\frac{d\theta_1^*}{d\lambda}-\frac{\partial\theta_3^*}{\partial\lambda}\right) \\ &= p_2^*\left(-\frac{p_2^*}{4w}+\frac{\partial\theta_1^*}{\partial\lambda}+\frac{\partial\theta_1^*}{\partial p_1^*}\frac{\partial p_1^*}{\partial\lambda}\right) \\ &+ p_2^*\left(\frac{3(1-w)p_2^*}{(2\lambda+w\lambda+4+5w)^2}\right) \end{aligned} \tag{B31}$$

$\frac{\partial\theta_2^*}{\partial\lambda}+\frac{\partial\theta_3^*}{\partial\lambda}=\frac{(4\lambda^2+4\lambda^2w+16\lambda+28\lambda w+\lambda^2w^2+10\lambda w^2+16+28w+37w^2)p_2^*}{4w(2\lambda+w\lambda+4+5w)^2}>0$. Furthermore it can be verified that $\frac{d\theta_1^*}{d\lambda}<0$. Hence, $\frac{d\Pi_2^*}{d\lambda}<0$, i.e., the profit from selling upgrades decreases with context-dependent preferences. □

Case B: Context-dependent preferences increase period 2 profit.

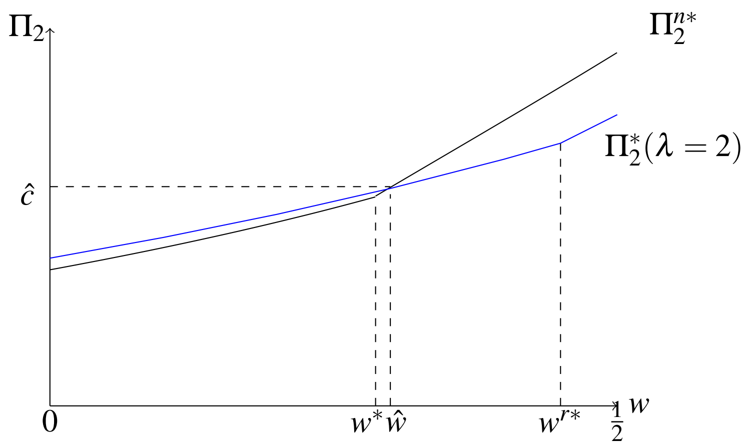
In this case, the profit of selling an upgrade is given in Equation B26. As λ increases, the change in this profit is given by

$$\begin{aligned}
\frac{d\Pi_2^*}{d\lambda} &= p_2^*\left(\frac{d\theta_1^*}{d\lambda}-\frac{\partial\theta_3^*}{\partial\lambda}\right)\\
&= p_2^*\left(\frac{\partial\theta_1^*}{\partial\lambda}+\frac{\partial\theta_1^*}{\partial p_1^*}\frac{\partial p_1^*}{\partial\lambda}+\frac{3(1-w)p_2^*}{(2\lambda+w\lambda+4+5w)^2}\right)\\
&= p_2^*\left(-\frac{6(1+5w)p_1^*}{(5\lambda+\lambda w+13-7w)^2}+\frac{3(\lambda+3)}{5\lambda+\lambda w+13-7w}\frac{\partial p_1^*}{\partial\lambda}\right)\\
&\quad +p_2^*\left(\frac{3(1-w)p_2^*}{(2\lambda+w\lambda+4+5w)^2}\right) \qquad \text{(B32)}
\end{aligned}$$

$-\frac{6(1+5w)p_1^*}{(5\lambda+\lambda w+13-7w)^2}<0$, $\frac{3(\lambda+3)}{5\lambda+\lambda w+13-7w}>0$, and $\frac{3p_2^*(1-\lambda)}{(2\lambda+\lambda w+4+5w)^2}>0$. $\frac{\partial p_1^*}{\partial\lambda}$ has the same sign with $\frac{\partial^2\Pi_1}{\partial p_1\partial\lambda}$ by the implicit function theorem and concavity of Π_1. $\frac{\partial^2\Pi_1}{\partial p_1\partial\lambda}$ is positive. Therefore, $\frac{\partial p_1^*}{\partial\lambda}>0$. The last two positive terms in Equation B32 offset the first negative term when w is not too large. In this case, $\frac{d\Pi_2^*}{d\lambda}>0$, i.e., the profit of selling upgrade is higher with context-dependent preferences. Even if w is large enough that $\frac{d\Pi_2^*}{d\lambda}<0$, this occurs when Case A applies without context-dependent preferences. Hence, period 2 profit decreases as discussed in Case A above.

It follows that under context-dependent preferences, Case B applies in a larger range of parameters, i.e., there exists a $w^{r*}>w^*$ such that Case B applies if and only if $w<w^{r*}$. Furthermore, there exists a $\hat{w}\in(w^*,w^{r*})$ such that the Case B profit with context-dependent preferences is equal to the Case A profit without context-dependent preferences. Define $\hat{c}=\Pi_2^*(w=\hat{w})-\frac{9}{100}$ at which the upgrade with a $w=\hat{w}$ breaks even. Since the profit is increasing in w, it is higher with context-dependent preferences for $c<\hat{c}$ and the reverse is true for $c>\hat{c}$ (see Figure A5 below).

Figure A5: Period 2 Profit Varies with Context Dependence



Lemma 6 *Context-dependent preferences have no impact on the firm's profit if the firm does not introduce upgrades.*

We show that under context-dependent preferences, the cut-off points $\hat{\theta}_1$ and $\hat{\theta}_2$ in Figure A1 do not change.

Period 2. In period 2, the reference price is $\frac{\hat{p}_2}{2}$. The reference quality is $\frac{1}{2}$. The consumer prefers buying the upgraded product over nothing if

$$\begin{aligned} \theta - \hat{p}_2 + \frac{\theta}{2} - \lambda\frac{\hat{p}_2}{2} &> 0 - \lambda\frac{\theta}{2} + \frac{\hat{p}_2}{2} \\ \theta &> \hat{p}_2 = \hat{\theta}_2 \end{aligned} \tag{B33}$$

Period 1. In period 1, the reference price is $\frac{\hat{p}_1}{2}$ and the reference quality is again $\frac{1}{2}$. The consumer prefers to buy early than to wait if

$$\begin{aligned} 2\theta - \hat{p}_1 + \frac{\theta}{2} - \lambda\frac{\hat{p}_1}{2} &> \theta - \hat{p}_2 - \lambda\frac{\theta}{2} + \frac{\hat{p}_1}{2} \\ \theta &> \frac{2\hat{p}_1}{3} = \hat{\theta}_1 \end{aligned} \tag{B34}$$

Given that the cut-off points do not change, consumer choices remain the same as when preferences are context-independent. Therefore, context-dependent preferences do not affect the firm when it does not introduce upgrades. $\square$.

Given that the period 2 profit is increasing in w and is higher under context-dependent preferences for $c < \hat{c}$, w needs to exceed a lower threshold for the period 2 profit to exceed $\frac{9}{100} + c$, the profit from selling the base product plus the fixed cost for upgrade introduction. Let $\underline{w}^r$ denote the threshold of w for upgrade introduction. As long as $c < \hat{c}$, $\underline{w}^r < \underline{w}$. The converse is true for $c > \hat{c}$. $\square$.

Proof of Proposition 3:

We prove Proposition 3 by showing two lemmas as follows.

Lemma 7 *Without context-dependent preferences, there exists a $\bar{w} > \underline{w}$ such that if $w \in (\underline{w}, min(\bar{w}, \frac{1}{2}))$, the firm introduces upgrades and the total profit is less than $\frac{9}{20} - c$.*

Suppose context-dependent preferences do not exist. If the firm does not introduce an upgrade, the equilibrium result is given after Equation B6. The total profit is $\hat{\Pi}_1^* = \frac{9}{20}$. If the firm introduces an upgrade, Case B applies when w is small. The equilibrium result is given after Equations B16 and the total profit is $\Pi_1^{b*} = \frac{(3-w)^2}{4(5-3w)} - c$, which is strictly lower than $\frac{9}{20} - c$ for $w \in (0, \frac{1}{2})$. If Case A applies, then the equilibrium outcome is given after Equation B12 and the total profit is $\Pi_1^{a*} = \frac{3w^4+6w^3-6w^2-6w-1}{(1+2w)(7w^2-5w-4)} - c$, increasing in w. Suppose $c = 0$ for now. If $w = 0.3$, then $\Pi_1^{a*} < \frac{9}{20}$. If $w = \frac{1}{2}$, then $\Pi_1^* > \frac{9}{20}$. Therefore, there exists a unique $\bar{w}$ such that if $w = \bar{w}$, $\Pi_1^* = \frac{9}{20}$. Since Π_1^{a*} increases with w, it exceeds $\frac{9}{20}$ if and only if $w > \bar{w}$. Recall that if $c = 0$, $\underline{w} \doteq 0.24 < 0.3$. Therefore, $\bar{w} > \underline{w}$. If $c > 0$, $\bar{w}$ needs to be even higher for introducing upgrade to maximize total profit. The proof is complete. □

Proposition 1 shows that the firm in period 2 introduces the upgrade as long as $w > \underline{w}$. Here we show that introducing upgrades maximizes total profit only if $w > \bar{w}$.

Lemma 8 *With context-dependent preferences, as long as $c < min(\bar{c}, c_{max})$, there exists a region $(\underline{w}, min(\bar{w}, \frac{1}{2}))$, a positive $\underline{\lambda}$, and a monotonically increasing function $g : (0, \frac{1}{2}) \to \mathbb{R}_+$ such that if $w \in (\underline{w}, min(\bar{w}, \frac{1}{2}))$ and $\lambda > max(\underline{\lambda}, g(w))$, then the monopolist's total profit is higher than $\frac{9}{20} - c$.*

If the firm introduces an upgrade, with context-dependent preferences, the firm's equilibrium period 2 profits in Cases A and B are

$$\begin{aligned} \Pi_2^{a*} &= \frac{N}{D} - c \\ \Pi_2^{b*} &= \frac{(5\lambda + \lambda w + 13 - 7w)^2 (2\lambda + \lambda w + 4 + 5w)}{6(8\lambda + \lambda w + 22 - 19w)^2 (\lambda + 3)} - c \end{aligned} \tag{B35}$$

where $N = (3\lambda^2 w + 6\lambda^2 - 8\lambda w^2 + 26\lambda w + 30\lambda - 112w^2 + 67w + 36)^2 w(2\lambda + \lambda w + 4 + 5w)$ and $D = 4(2\lambda + \lambda w + 4 + 11w)(\lambda + 3)(2\lambda^2 + \lambda^2 w - 3\lambda w^2 + 8\lambda w + 10\lambda - 39w^2 + 21w + 12)^2$. If $\lambda = 1$, these profits reduce to that without context-dependent preferences. Lemma 3 shows that for $w > w^*$, Case A applies and for $w > w^*$, Case B applies. Let $g : (0, \frac{1}{2}) \to \mathbb{R}_+$ denote the threshold of λ above which Case B applies, then $g(w) = 1$ for $w = w^*$. Define $\Delta\Pi_2 = \Pi_2^{b*} - \Pi_2^{a*}$. $g(w)$ is monotonically increasing in w because $\frac{\partial \lambda}{\partial w} = -\frac{\frac{\partial \Delta\Pi_2}{\partial w}}{\frac{\partial \Delta\Pi_2}{\partial \lambda}} > 0$ in the relevant region.

Consider the region that $\lambda > g(w)$ so that Case B applies. Suppose $\underline{w}^r < \underline{w}$ then the firm introduces upgrades for $w > \underline{w}$. In this case, if $\lambda = 1$, $\Pi_1^{b*} = \frac{(3-w)^2}{4(5-3w)} - c < \frac{9}{20} - c$

for $w \in (0, \frac{1}{2})$. If $\lambda = 2$, $\Pi_1^{b*} = \frac{(23-5w)^2}{30(38-17w)} - c > \frac{9}{20} - c$. Π_1^{b*} is increasing in λ. Hence, there exits a $\underline{\lambda} \in (1,2)$ such that for $\lambda > max\,(\underline{\lambda}, g(w))$, $\Pi_1^{b*} > \frac{9}{20} - c$. Suppose $\underline{w}^r > \underline{w}$. For $w \in (\underline{w}^r, min(\bar{w}, \frac{1}{2}))$, the firm introduces an upgrade and the total profit is higher than $\frac{9}{20} - c$ as in the previous case. For $w \in (\underline{w}, \underline{w}^r)$, the firm under context-dependent preferences doesn't introduce the upgrade and receive the total profit $\frac{9}{20}$, which is also higher than $\frac{9}{20} - c$. $\square$

Proof of Proposition 4:

Case A: Selling the upgrade to existing consumers and new consumers.

In this case, prices of the base product (p_1^*) and the upgraded product (p_2^*) both decrease with λ. With context-dependent preferences, p_2^* is given in Equation B22.

$$\frac{dp_2^*}{d\lambda} = \frac{\partial p_2^*}{\partial \lambda} + \frac{\partial p_2^*}{\partial \theta_1^*}\frac{d\theta_1^*}{d\lambda} = \frac{\partial G}{\partial \lambda}(1+\theta_1^*) + G\left(\frac{\partial \theta_1^*}{\partial \lambda} + \frac{\partial \theta_1^*}{\partial p_1^*}\frac{\partial p_1^*}{\partial \lambda}\right) < 0 \tag{B36}$$

where $G = \frac{2w(4+5w+2\lambda+w\lambda)}{(3+\lambda)(4+11w+2\lambda+w\lambda)}$. It is easy to verify that $\frac{\partial G}{\partial \lambda} < 0$ and $\frac{d\theta_1^*}{d\lambda} < 0$. Therefore, $\frac{dp_2^*}{d\lambda} < 0$, i.e., price of the upgraded product decreases with context-dependent preferences. p_1^* is solved from taking the first order condition of Equation B12. We determine the sign of $\frac{\partial p_1^*}{\partial \lambda}$ using the implicit function theorem that gives $\frac{\partial p_1^*}{\partial \lambda} = -\frac{\frac{\partial^2 \Pi_1}{\partial p_1 \partial \lambda}}{\frac{\partial^2 \Pi_1}{\partial p_1^2}}$. The profit function is concave in price, i.e., $\frac{\partial^2 \Pi_1}{\partial p_1^2} < 0$. In the region of considered parameters, $\frac{\partial^2 \Pi_1}{\partial p_1 \partial \lambda} < 0$. Therefore, $\frac{\partial p_1^*}{\partial \lambda} < 0$.

λ decreases p_2^* to a larger degree than it decreases p_1^*. Given that θ_1^* is a function of p_1^*, we can write the effect of λ on p_2^* as a function of the effect of λ on p_1^* as follows.

$$\frac{dp_2^*}{d\lambda} = \frac{\partial p_2^*}{\partial \lambda} + \frac{\partial p_2^*}{\partial p_1^*}\frac{\partial p_1^*}{\partial \lambda} \tag{B37}$$

The two terms correspond to the direct and strategic effects of λ on p_2^* directly and through affecting p_1^* strategically. $\frac{\partial p_2^*}{\partial \lambda} < 0$ and $\frac{\partial p_1^*}{\partial \lambda} < 0$ reflecting the price sensitivity effect. $\frac{\partial p_2^*}{\partial p_1^*} > 0$ reflecting the strategic competition. Over the considered region of w and λ, $\frac{dp_2^*}{d\lambda} < \frac{\partial p_1^*}{\partial \lambda}$, i.e, price of the upgrade decreases more than the price of the base product with context-dependent preferences. □

Case B: Selling the upgrade to new consumers only.

In this case, prices of the base product (p_1^*) and the upgraded product (p_2^*) are given after Equation B16. By the implicit function theorem and concavity of the profit function, the sign of $\frac{\partial p_1^*}{\partial \lambda}$ is the same as the sign of $\frac{\partial^2 \Pi_1}{\partial p_1 \partial \lambda} = -\frac{6p_1^*(-46w+113w^2+\lambda w^2-26\lambda w-11\lambda-31)}{(5\lambda+\lambda w+13-7w)^3} > 0$. Hence, $\frac{\partial p_1^*}{\partial \lambda} > 0$.

$$\frac{dp_2^*}{d\lambda} = \frac{\partial p_2^*}{\partial \lambda} + \frac{\partial p_2^*}{\partial \theta_1^*}\frac{d\theta_1^*}{d\lambda} = \frac{2(1-w)\theta_1^*}{3(\lambda+3)^2} - \frac{2\lambda+\lambda w+4+5w}{3(\lambda+3)}\frac{6(2w^2-1+5w)}{(8\lambda+\lambda w+22-19w)^2} \tag{B38}$$

$\frac{2(1-w)\theta_1^*}{3(\lambda+3)^2} > 0$, $\frac{2\lambda+\lambda w+4+5w}{3(\lambda+3)} > 0$, and $\frac{6(2w^2-1+5w)}{(8\lambda+\lambda w+22-19w)^2}$ can take either sign. Overall $\frac{dp_2^*}{d\lambda} > 0$ if w is lower than a threshold and $\frac{dp_2^*}{d\lambda} < 0$ if w exceeds that threshold. If p_2 decreases, since p_1 increases, the price dispersion is larger. Even if p_2 increases, we show that it increases to a smaller degree than the increase in p_1.

$$\begin{aligned}\frac{dp_2^*}{d\lambda} &= \frac{\partial p_2^*}{\partial \lambda} + \frac{\partial p_2^*}{\partial \theta_1^*}\left(\frac{\partial \theta_1^*}{\partial \lambda} + \frac{\partial \theta_1^*}{\partial p_1^*}\frac{\partial p_1^*}{\partial \lambda}\right) \\ &= \frac{2(1-w)\theta_1^*}{3(\lambda+3)^2} + \frac{2\lambda+\lambda w+4+5w}{3(\lambda+3)} \\ &\quad \left(-\frac{6(1+5w)p_1^*}{(5\lambda+\lambda w+13-7w)^2} + \frac{3(\lambda+3)}{5\lambda+\lambda w+13-7w}\frac{\partial p_1^*}{\partial \lambda}\right)\end{aligned} \tag{B39}$$

All terms are positive except that $-\frac{6(1+5w)p_1^*}{(5\lambda+\lambda w+13-7w)^2} < 0$, driving $\frac{\partial p_2^*}{\partial \lambda} < \frac{\partial p_1^*}{\partial \lambda}$. □

Proof of Proposition 5:

Suppose $c < \hat{c}$, i.e., $\underline{w} \in (0, \hat{w})$. Three cases for which consumer surplus changes differently can arise. (1) $w < \underline{w}^r < \underline{w}$. The firm doesn't introduce upgrade either context-dependent preferences exist or not. (2) $w \in (\underline{w}^r, \underline{w})$. The firm would introduce an upgrade only under context-dependent preferences. (3)$w \in (\underline{w}, \hat{w})$. The firm introduces an upgrade even without context-dependent preferences. If $c > \hat{c}$, i.e., $\underline{w} > \hat{w}$, then there are three cases. (4) $w < \underline{w} < \underline{w}^r$. The firm does not introduce upgrades in either case. (5) $w \in (\underline{w}, \underline{w}^r)$. The firm introduces an upgrade only if context-dependent preferences do not exist. (6)$w > \underline{w}^r > \underline{w}$. The firm introduces an upgrade in either case.

We show that consumer surplus increases when the firm introduces upgrades and Case A applies. Proof for the other cases can be derived analogously.

First, we show that holding $\lambda = 1$, i.e, prices and consumption pattern remain the same as in the absence of context-dependent preferences, consumer surplus with context-dependent preferences (denoted by CS^r) is higher than the consumer surplus without context-dependent preferences (denoted by CS). In Case A, consumer surplus can be written as below. To conserve notations, we omit the superscript * that indicates equilibrium outcome.

$$
\begin{aligned}
CS^r &= \int_0^{\theta_3}\left[\frac{p_1+p_2}{2}-\lambda\theta\left(\frac{1}{2}+\frac{2+w}{3}\right)\right]f(\theta)\,\mathrm{d}\theta \\
&+\int_{\theta_3}^{\theta_1}\left[\theta(1+w)-p_2+\frac{p_1}{2}-\frac{\lambda\theta}{2}+\theta\left(1+w-\frac{2+w}{3}\right)-\lambda\frac{p_2}{2}\right]f(\theta)\,\mathrm{d}\theta \\
&+\int_{\theta_1}^{\theta_2}\left[2\theta-p_1+\frac{\theta}{2}-\lambda\frac{p_1}{2}+\theta\left(1-\frac{2+w}{3}\right)+\frac{p_2}{2}\right]f(\theta)\,\mathrm{d}\theta \\
&+\int_{\theta_2}^{1}\left[\theta(2+w)-p_1-p_2+\frac{\theta}{2}-\lambda\frac{p_1}{2}+\theta\left(1+w-\frac{2+w}{3}\right)-\lambda\frac{p_2}{2}\right]f(\theta)\,\mathrm{d}\theta \\
&= CS^r_{(0,0)}+CS^r_{(0,2)}+CS^r_{(1,1)}+CS^r_{(1,2)} \qquad \text{(B40)}
\end{aligned}
$$

where the CS^r is decomposed into four terms of $CS^r_{(\cdot,\cdot)}$ that correspond to the consumer surplus in the separate regions in Figure A2. Let $\lambda = 1$. We analyze each term separately.

$$
\begin{aligned}
CS^r_{(0,0)}(\lambda=1) &= \int_0^{\theta_3}\left[\frac{p_1+p_2}{2}-\theta\left(\frac{1}{2}+\frac{2+w}{3}\right)\right]f(\theta)\,\mathrm{d}\theta \\
&= \int_0^{\theta_3}\left[\frac{p_1+p_2}{2}-\theta\frac{7+2w}{6}\right]f(\theta)\,\mathrm{d}\theta \qquad \text{(B41)}
\end{aligned}
$$

$CS^r_{(0,0)}(\lambda=1) > 0$ as long as $\theta < \frac{3(p_1+p_2)}{7+2w} = \tilde{\theta}_3 > \theta_3$. Therefore, $CS^r_{(0,0)}(\lambda=1) > 0$ in the region $(0,\theta_3)$.

$$
\begin{aligned}
CS^r_{(0,2)}(\lambda=1) &= \int_{\theta_3}^{\theta_1}\left[\theta(1+w)-p_2+\frac{p_1}{2}-\frac{\theta}{2}+\theta\left(1+w-\frac{2+w}{3}\right)-\frac{p_2}{2}\right]f(\theta)\,\mathrm{d}\theta \\
&= CS_{(0,2)}+\int_{\theta_3}^{\theta_1}\left[\frac{p_1}{2}-\frac{\theta}{2}+\theta\left(1+w-\frac{2+w}{3}\right)-\frac{p_2}{2}\right]f(\theta)\,\mathrm{d}\theta \\
&= CS_{(0,2)}+\int_{\theta_3}^{\theta_1}\left[\frac{p_1-p_2}{2}+\theta\frac{4w-1}{6}\right]f(\theta)\,\mathrm{d}\theta \qquad \text{(B42)}
\end{aligned}
$$

Because $p_1 > p_2$, if $4w-1>0$ then $\frac{p_1-p_2}{2}+\theta\frac{4w-1}{6} > 0$. If $4w-1<0$, then $\frac{p_1-p_2}{2}+\theta\frac{4w-1}{6} > 0$ as long as $\theta < \frac{3(p_1-p_2)}{1-4w} = \tilde{\theta}_4$. For $w \in (0,\frac{1}{4})$, $\tilde{\theta}_4 > \theta_1$. Therefore, over the region $\theta \in (\theta_3,\theta_1)$, $\frac{p_1-p_2}{2}+\theta\frac{4w-1}{6} > 0$. It follows that in this region $CS^r_{(0,2)}(\lambda=1) > CS_{(0,2)}$.

$$CS^r_{(1,1)}(\lambda=1) = \int_{\theta_1}^{\theta_2}\left[2\theta - p_1 + \frac{\theta}{2} - \frac{p_1}{2} + \theta\left(1-\frac{2+w}{3}\right) + \frac{p_2}{2}\right] f(\theta)\,\mathrm{d}\theta$$
$$= CS_{(1,1)} + \int_{\theta_1}^{\theta_2}\left[\frac{\theta}{2} - \frac{p_1}{2} + \theta\left(1-\frac{2+w}{3}\right) + \frac{p_2}{2}\right] f(\theta)\,\mathrm{d}\theta$$
$$= CS_{(1,1)} + \int_{\theta_1}^{\theta_2}\left[\theta\frac{5-2w}{6} - \frac{p_1-p_2}{2}\right] f(\theta)\,\mathrm{d}\theta \qquad \text{(B43)}$$

$\theta\frac{5-2w}{6} - \frac{p_1-p_2}{2} > 0$ as long as $\theta > \frac{3(p_1-p_2)}{5-2w} = \frac{3(w-1)(-2-3w+3w^2)}{(2w-5)(7w^2-5w-4)} = \tilde{\theta}_1$. For $w \in (0, \frac{1}{2})$, $\tilde{\theta}_1 < \theta_1$. Therefore, for $\theta \in (\theta_1, \theta_2)$, $\theta\frac{5-w}{6} - \frac{p_1-p_2}{2} > 0$. It follows that $CS^r_{(1,1)}(\lambda=1) > CS_{(1,1)}$.

$$CS^r_{(1,2)}(\lambda=1) = \int_{\theta_2}^{1}\left[\theta(2+w) - p_1 - p_2 + \frac{\theta}{2} - \frac{p_1}{2} + \theta\left(1+w-\frac{2+w}{3}\right) - \frac{p_2}{2}\right] f(\theta)\,\mathrm{d}\theta$$
$$= CS_{(1,2)} + \int_{\theta_2}^{1}\left[\frac{\theta}{2} - \frac{p_1}{2} + \theta\left(1+w-\frac{2+w}{3}\right) - \frac{p_2}{2}\right] f(\theta)\,\mathrm{d}\theta$$
$$= CS_{(1,2)} + \int_{\theta_2}^{1}\left[\theta\frac{5+4w}{6} - \frac{p_1+p_2}{2}\right] f(\theta)\,\mathrm{d}\theta \qquad \text{(B44)}$$

$\theta\frac{5+4w}{6} - \frac{p_1+p_2}{2} > 0$ as long as $\theta > \frac{3(p_1+p_2)}{5+4w} = \frac{3(4w^4+11w^3-10w^2-11w-2)}{(5+4w)(1+2w)(7w^2-5w-4)} = \tilde{\theta}_2$. Over the region that $w \in (0, \frac{1}{2})$, $\tilde{\theta}_2 < \theta_2$. Therefore, $\theta\frac{5+4w}{6} - \frac{p_1+p_2}{2} > 0$ is always satisfied for $\theta \in (\theta_2, 1)$. It follows that $CS^r_{(1,2)}(\lambda=1) > CS_{(1,2)}$

Since each component of $CS^r(\lambda=1)$ is higher than the corresponding component of CS, $CS^r(\lambda=1) > CS$. Consequently, if λ is close to 1, $CS^r > CS$.

Second, we show that as λ increases, CS^r decreases. Again we analyze each component separately.

$$\frac{dCS^r_{(0,0)}}{d\lambda} = \frac{\theta_3}{2}\left(\frac{\partial p_1}{\partial\lambda} + \frac{dp_2}{d\lambda}\right) + \frac{p_1+p_2}{2}\frac{d\theta_3}{d\lambda} - \frac{7+2w}{6}\left(\lambda\frac{d\theta_3}{d\lambda}\theta_3 + \frac{\theta_3^2}{2}\right) \qquad \text{(B45)}$$

where $\frac{\partial p_1}{\partial \lambda} < 0$, $\frac{dp_2}{d\lambda} < 0$, and $\frac{d\theta_3}{d\lambda} < 0$. The sign of $\frac{dCS^r_{(0,0)}}{d\lambda}$ is ambiguous.

$$\begin{aligned}\frac{dCS^r_{(0,2)}}{d\lambda} &= \left(2+2w-\frac{\lambda}{2}-\frac{2+w}{3}\right)\left(\theta_1\frac{d\theta_1}{d\lambda}-\theta_3\frac{d\theta_3}{d\lambda}\right)\\ &\quad -\frac{\theta_1^2-\theta_3^2}{4}-\left(\frac{d\theta_1}{d\lambda}-\frac{d\theta_3}{d\lambda}\right)\left(p_2-\frac{p_1}{2}+\lambda\frac{p_2}{2}\right)\\ &\quad -(\theta_1-\theta_3)\left(\frac{dp_2}{d\lambda}-\frac{1}{2}\frac{\partial p_1}{\partial\lambda}+\frac{p_2}{2}+\frac{\lambda}{2}\frac{dp_2}{d\lambda}\right) \qquad \text{(B46)}\end{aligned}$$

whose sign is negative.

$$\begin{aligned}\frac{dCS^r_{(1,1)}}{d\lambda} &= (\theta_1-\theta_2)\left(\frac{\partial p_1}{\partial\lambda}+\frac{p_1}{2}+\frac{\lambda}{2}\frac{\partial p_1}{\partial\lambda}-\frac{1}{2}\frac{dp_2}{d\lambda}\right)\\ &\quad +\left(-p_1-\lambda\frac{p_1}{2}+\frac{p_2}{2}\right)\left(\frac{\partial\theta_2}{\partial\lambda}-\frac{\partial\theta_1}{\partial\lambda}\right)\\ &\quad +\left(\frac{7}{2}-\frac{2+w}{3}\right)\left(\theta_2\frac{\partial\theta_2}{\partial\lambda}-\theta_1\frac{\partial\theta_1}{\partial\lambda}\right) \qquad \text{(B47)}\end{aligned}$$

whose sign is ambiguous.

$$\begin{aligned}\frac{dCS^r_{(1,2)}}{d\lambda} &= -\left(\frac{7}{2}+2w-\frac{2+w}{3}\right)\theta_2\frac{\partial\theta_2}{\partial\lambda}-\left(\frac{\partial p_1}{\partial\lambda}+\frac{dp_2}{d\lambda}\right)\left(1+\frac{\lambda}{2}\right)(1-\theta_2)\\ &\quad -(p_1+p_2)\frac{1-\theta_2}{2}+(p_1+p_2)\left(1+\frac{\lambda}{2}\right)\frac{d\theta_2}{d\lambda} \qquad \text{(B48)}\end{aligned}$$

whose sign is negative. All four components combined are negative. Therefore, CS^r is decreasing with λ.

Given that $CS^r > CS$ when $\lambda = 1$ and CS^r is decreasing in λ, it follows that there exists $\tilde{\lambda} > 1$ such that if λ does not exceed $\tilde{\lambda}$, $CS^r > CS$ remains valid.

Now we discuss social welfare. In the considered region, the firm introduces upgrades regardless whether context-dependent preferences exist or not. First, without context-dependent preferences, the firm's total profit is $\hat{\Pi}_1^* = \frac{3w^4+6w^3-6w^2-6w-1}{(1+2w)(7w^2-5w-4)}$ as given in the analysis of the benchmark case. With context-dependent preferences, if $\lambda = 1$, the firm's total profit reduces to $\hat{\Pi}_1^*$. Therefore if $\lambda = 1$, the social welfare is higher with context-dependent preferences because the consumer surplus is higher and the firm's total profit is the same as that without context-dependent preferences. As λ increases, the firm's total profit decreases on top of the decrease in consumer surplus. Therefore, in a subset of the region where consumer surplus is higher with context-dependent preferences, the increased consumer surplus offsets the decrease in the firm's profit and social welfare is improved by the context-dependent preferences. Here we show that the firm's total profit under context-dependent preferences is decreasing in λ.

$$\begin{aligned}
\Pi_1 &= p_1(1-\theta_1)+p_2(1-\theta_2+\theta_1-\theta_3)-c \\
\frac{d\Pi_1}{d\lambda} &= (1-\theta_2+\theta_1-\theta_3)\frac{dp_2}{d\lambda}-(p_1-p_2)\frac{d\theta_1}{d\lambda}-p_2\left(\frac{d\theta_2}{d\lambda}+\frac{d\theta_3}{d\lambda}\right)+\frac{dp_1}{d\lambda}(1-\theta_1) \qquad \text{(B.49)}
\end{aligned}$$

In equilibrium, $(1-\theta_2+\theta_1-\theta_3) > 0$ and $\frac{dp_2}{d\lambda} < 0$, hence, the first term is negative. $p_1 > p_2$ and $\frac{d\theta_1}{d\lambda} < 0$, hence the second term $-(p_1-p_2)\frac{\partial d_1}{d\lambda}$ is positive. $\frac{d\theta_2}{d\lambda} + \frac{d\theta_3}{d\lambda}$ is negative. The third term $-p_2\left(\frac{d\theta_2}{d\lambda}+\frac{d\theta_3}{d\lambda}\right)$ is positive. $\frac{dp_1}{d\lambda}$ is negative. The negative terms dominate the positive terms. Overall, $\frac{d\Pi_1}{d\lambda} < 0$. □

APPENDIX C

PROOFS FOR CHAPTER 3

Details of the Random-Coefficient Logit Model

Specifically, we model individual coefficients in the utility function to follow a normal distribution with mean coefficients:

$$\begin{pmatrix} \gamma_i \\ \alpha_i \end{pmatrix} = \begin{pmatrix} \gamma \\ \alpha \end{pmatrix} + \Sigma v_i, \qquad v_i \sim P_v(v) \tag{C1}$$

where $P_v(\cdot)$ is the distribution of v_i. We assume that it is a standard multivariate normal distribution. We can rewrite the utility function as

$$\begin{aligned} u_{ijt} \quad = \quad & \gamma_s d_{jt} + \alpha^1 pri_{jt} + \alpha^2 ads_{jt} + \beta' x_{jt} + \eta_{jt} \\ & + \Delta\gamma_{is} d_{jt} + \Delta\alpha_i^1 pri_{jt} + \varepsilon_{ijt} \end{aligned} \tag{C2}$$

where $\gamma_s d_{jt} + \alpha^1 pri_{jt} + \alpha^2 ads_{jt} + \beta' x_{jt} + \eta_{jt}$ are the mean utility that consumers derive from car model j in time t, and $\Delta\gamma_{is} d_{jt} + \Delta\alpha_i^1 pri_{jt}$ are the individual consumer i's deviation from the mean utility. Our focal interest is in $\gamma_s, s \in \{h, l\}$, i.e., the impact of design differentiation on consumer preferences for high-end and low-end products separately. Our hypothesis H_1 states that $\gamma_h > 0$ and $\gamma_l < 0$.[*]

The term η_{jt} in (C2) captures unobserved demand factors of car model j in period

[*] Essentially, we are interested in the main effect of design differentiation (d) on consumer preferences and its interaction with the dummy variable that indicates if a product is a high-end product (versus a low-end product). Our hypothesis (H_1) is equivalent to that the base effect of design differentiation on consumer preferences is negative; however, a product being a high-end product positively moderates the main effect of design differentiation on consumer preferences such that the overall effect of design differentiation of a high-end product on consumer preferences is positive.

t. ε_{ijt} is the idiosyncratic error term. We normalize the intrinsic utility of the outside good to zero and the total utility of the outside good is only the idiosyncratic error term: $u_{i0t} = \varepsilon_{i0t}$. We further assume that ε_{ijt} follows an i.i.d. Type I extreme value distribution. We assume that each consumer purchases one car model that gives the highest utility. The set of consumers that purchase car model j in time t is:

$$A_{jt} = \left\{(v_i; \varepsilon_{i0t}, ..., \varepsilon_{iJt}) | u_{ijt} \geq u_{ilt} \quad \forall l = 0, 1, ..., J\right\} \tag{C3}$$

The market share of the car model j in time t is integrating over the mass of consumers in the region A_{jt}:

$$s_{jt} = \int_{A_{jt}} dP_{\varepsilon}(\varepsilon) dP_{v}(v) \tag{C4}$$

Robustness Check

In the main empirical model, we adopt the identifying assumption in previous literature that car characteristics including design and functional attributes are exogenous, or at least determined prior to the revelation of consumers' valuation of the unobserved product characteristics (Berry et al. 1995, Nevo 2000, Sudhir 2001). In this section, we show that our results that support H_1 still hold when we control for potential endogeneity of design characteristics.

Endogenous Design Variables

We draw upon the institutional details about the car development process to look for proper instruments for design differentiation variables. Very briefly, a typical car development process comprises of three stages (Sörenson 2006, Weber 2009, Whitefoot et al.2012, The Toronto Star 2010). In the first stage, firms make long-term product positioning strategies for a new car, such as the segment the new car competes in (i.e. luxury and economy), the vehicle size (i.e. full size, midsize and compact), the product classification schemes (i.e. regular and sporty/specialty), and country of origin (i.e. US, Europe, Japan and South Korea). These long-run product positioning strategies are relatively fixed over time and serve as guidelines as well as constraints for the later design and marketing decisions. In the second stage, firms make mid-term car design decisions by setting the exterior aesthetic design and internal technological attributes of cars. The last stage of the car design process is the production and sales of vehicles. In this stage, firms make short-run marketing decisions, including pricing and advertising, to support sales.

Given the sequence of decisions made throughout the car design process, we make two identification assumptions. First, we assume that long-term decision variables including cars' country of origin, size, product classification, product segmentation and safety rating are exogenous. This assumption is plausible because the long-term decisions are made ex ante prior to firms making design decisions or marketing decisions. Thus, they are not correlated with ex post short-term and mid-term demand shocks affecting marketing and design decisions. Moreover, they are fixed or rarely change over the life cycle of a car model. Second, we assume that the mid-term decision variables on cars' technical attributes including horsepower, fuel efficiency, and reliability are exogenous. These technical attributes are uncorrelated with design differentiation variables. This is because the two sets of decisions are made separately by different design divisions and do not necessarily change at the same time. Even when they both change at the same time, the direction and magnitude of change in design and technical attributes may not be correlated (see Table 2). Therefore, it is reasonable to assume that a firm's decisions on technical attributes, including HP, fuel efficiency and reliability, are independent of its decisions on product design. In other words, the mid-term technical attribute variables can be treated as exogenous in our study, when we account for the endogeneity of product design.

Specifically, We use functions of long-run car attributes determined in the first stage of the product design process as instruments for mid-run endogenous design differentiation variables that are determined later in the process. We first identify the long-run car attribute that is correlated with design differentiation variables: product classification (regular and sporty/specialty). While sports cars (e.g. Ford Mustang) and specialty cars (e.g. Mini Cooper) usually have more unique designs, regular cars (e.g. Toyota Camry) tend to have more typical designs. Indeed, we find a significant negative correlation between product classification and the product design variable, d(see Table 2), meaning that regular cars are less differentiated in design than sporty or specialty cars. Following a similar logic as creating instruments for marketing activities, we create two similarity subsets for each car based on country of origin and (Luxury vs. Economy) classifications. We compute the within-brand average and across-brand average of the product classification for the two similarity subsets. We then use own characteristics minus the within-brand average (across-brand average) as instruments. Such instruments reflect the difference between own characteristics and the average characteristics, just like design differentiation is operationalized as the distance between own look and the average look in own brand. We estimate the model using the instruments for design differentiation variables. Results are presented in Table A1 and are quantitatively consistent with results in the main model (Model 2). Particularly, design differentiation has a significantly positive impact on consumers' preferences for high-end cars and a significantly negative impact on consumers' preferences for low-end cars.

Quadratic Prices

We determine the standing of a car model in its brand to be either high-end or low-end by comparing the price of the car model with the average price in its brand. Although prices change over time, the relative standing of a car model in its brand, as to whether it is a high-end car or a low-end car does not change over time. In order to rule out the impact of price variations on the estimates of the coefficients of design differentiation variables for high-end and low-end car models, we add a quadratic term of the price variable in the model. Results are presented in Table A2 and are qualitatively consistent with those in the main model.

Analysis of a Monopoly

For completeness, we consider the case of a monopoly that sells high-end and low-end status products and needs to decide whether to use the same or different designs for two types of products. To be consistent with the duopoly setting, we consider fully-covered market. Prices for the high-end and low-end products are:

$$p_h = r_h - t_h(a_h - 1)^2 + \gamma_h d \tag{C5}$$

$$p_l = r_l - t_l(a_l - 1)^2 - \gamma_l d \tag{C6}$$

The monopoly profits are $\Pi = \alpha\left[r_h - t_h(a_h-1)^2 + \gamma_h d - c\right] + (1-\alpha)\left[r_l - t_l(a_l-1)^2 - \gamma_l d\right] - m \cdot d$. It follows that the monopolist diversifies design if and only if:

$$\Pi[d=1] - \Pi[d=0] = \gamma_h\alpha - \gamma_l(1-\alpha) - m > 0 \quad \text{(C7)}$$

In a competitive setting, brands' incentives to diversify or to unify design deviate from the above condition that guides a monopolist's design decision. Particularly, we show that brands want to strategically avoid competition by adopting a different design strategy that that the competitor chooses. The asymmetric design choices can emerge in a duopoly setting, which is the focus of our main analysis.

Proof of Proposition 1

We show that when $\gamma_h \in (\hat{\gamma}_1, \hat{\gamma}_2)$, brand profits are higher with asymmetric design strategies than with symmetric design strategies. By Lemma 1, with symmetric design strategies, brand profits are the highest when brands choose symmetric unification and the profits are given in Table A3. We denote brand profits under the symmetric regime by $\Pi_a^*(U,U)$ or $\Pi_b^*(U,U)$. In the asymmetric regime, A unifies design and B diversifies design. We denote their profits by $\Pi_a^*(U,D)$ and $\Pi_b^*(U,D)$ respectively.

Comparing brand profits in asymmetric and symmetric regimes, we obtain that:

$$\Delta_a = \Pi_a^*(U,D) - \Pi_a^*(U,U) = \frac{1}{18}\left[\frac{\alpha\gamma_h^2}{t_h(b_h-a_h)} + \frac{(1-\alpha)\gamma_l^2}{t_l(b_l-a_l)}\right] - \frac{\alpha\gamma_h - (1-\alpha)\gamma_l}{3} \quad \text{(C8)}$$

$$\Delta_b = \Pi_b^*(U,D) - \Pi_b^*(U,U) = \frac{1}{18}\left[\frac{\alpha\gamma_h^2}{t_h(b_h-a_h)} + \frac{(1-\alpha)\gamma_l^2}{t_l(b_l-a_l)}\right] + \frac{\alpha\gamma_h - (1-\alpha)\gamma_l}{3} - m \quad \text{(C9)}$$

With asymmetric design strategies, $\theta_h^* = \frac{1}{2} - \frac{\gamma_h}{6t_h(b_h-a_h)}$ and $\theta_l = \frac{1}{2} + \frac{\gamma_l}{6t_l(b_l-a_l)}$. For brands to be active in both markets, i.e., $\theta_s \in (0,1), s \in \{h,l\}$, it requires that $\gamma_l < 3t_l(b_l - a_l)$ and $\gamma_h < 3t_h(b_h - a_h)$. We prove the proposition through a series of claims.

Claim 4 *As long as* $(1-\alpha)t_l(b_l-a_l) < 3\alpha t_h(b_h-a_h) - 2m$*, there exists a* $\hat{\gamma}_1 \in (0, 3t_h(b_h - a_h))$ *such that* $\Delta_b > 0$ *iff* $\gamma_h > \hat{\gamma}_1$.

$\frac{\partial \Delta_b}{\partial \gamma_h} = \frac{\alpha\gamma_h}{9(b_h-a_h)t_h} + \frac{\alpha}{3} > 0$, i.e., Δ_b is increasing in γ_h. If $\gamma_h = 0$, then $\Delta_b = -\frac{(1-\alpha)\gamma_l[6t_l(b_l-a_l)-\gamma_l]}{18t_l(b_l-a_l)} - m < 0$. Given that $\gamma_h < 3t_h(b_h - a_h)$, if when $\gamma_h = 3t_h(b_h - a_h)$, $\Delta_b > 0$, then there exists a $\hat{\gamma}_1 \in (0, 3t_h(b_h - a_h))$ such that if $\gamma_h = \hat{\gamma}_1$, $\Delta_b = 0$, and given that Δ_b is increasing in γ_h, it will also imply that $\Delta_b > 0$ iff $\gamma_h > \hat{\gamma}_1$. $\Delta_b|_{\gamma_h=3t_h(b_h-a_h)} = \frac{3t_h(b_h-a_h)}{2} - \frac{(1-\alpha)\gamma_l}{3}\left(1 - \frac{\gamma_l}{6t_l(b_l-a_l)}\right) - m$, which is decreasing in γ_l for $\gamma_l < 3t_l(b_l - a_l)$. A sufficient condition for $\Delta_b|_{\gamma_h=3t_h(b_h-a_h)} > 0$ for any value of $\gamma_l < 3t_l(b_l - a_l)$ is that when $\gamma_l = 3t_l(b_l - a_l)$, $\Delta_b|_{\gamma_h=3t_h(b_h-a_h)} > 0$. This condition is equivalent to that $\Delta_b|_{\gamma_h=3t_h(b_h-a_h),\gamma_l=3t_l(b_l-a_l)} = \frac{1}{2}[3\alpha t_h(b_h-a_h) - (1-\alpha)t_l(b_l-a_l)] - m > 0$ or $(1-\alpha)t_l(b_l-a_l) < 3\alpha t_h(b_h-a_h) - 2m$.

Claim 5 $\hat{\gamma}_1$ *is concave and increasing in* γ_l.

By the implicit function theorem, we have

$$\frac{\partial \hat{\gamma}_1}{\partial \gamma_l} = -\frac{\frac{\partial \Delta_b}{\partial \gamma_l}}{\frac{\partial \Delta_b}{\partial \gamma_h}} > 0 \tag{C10}$$

where $\frac{\partial \Delta_b}{\partial \gamma_l} = -\frac{(1-\alpha)[3t_l(b_l-a_l)-\gamma_l]}{9t_l(b_l-a_l)} < 0$ given the condition that $\gamma_l < 3t_l(b_l - a_l)$, and $\frac{\partial \Delta_b}{\partial \gamma_h} = \frac{\alpha[\gamma_h+3t_h(b_h-a_h)]}{9t_h(b_h-a_h)} > 0$.

$$\frac{\partial^2 \hat{\gamma}_1}{\partial \gamma_l^2} = -\frac{(1-\alpha)t_h(b_h-a_h)}{\alpha t_l(b_l-a_l)\,[3t_h(b_h-a_h)+\gamma_h]} < 0 \tag{C11}$$

Hence, $\hat{\gamma}_1$ is a concave function of γ_l.

Claim 6 *There exists a $\hat{\gamma}_2 > 0$ such that $\Delta_a > 0$ iff $\gamma_h < \hat{\gamma}_2$. If $(1-\alpha)t_l(b_l - a_l) > \frac{1}{3}\alpha t_h(b_h - a_h)$, then there exists $\gamma_h < 3t_h(b_h - a_h)$ and $\gamma_l < 3t_l(b_l - a_l)$ such that $\Delta_a > 0$.*

$\frac{\partial \Delta_a}{\partial \gamma_h} = \frac{\alpha[\gamma_h - 3t_h(b_h - a_h)]}{9t_h(b_h - a_h)} < 0$ given that $\gamma_h < 3t_h(b_h - a_h)$. Hence, Δ_a is decreasing in γ_h. If $\gamma_h = 0$, then $\Delta_a = \frac{(1-\alpha)\gamma_l^2}{18t_l(b_l - a_l)} + \frac{(1-\alpha)\gamma_l}{3} > 0$ for $\gamma_l > 0$. Hence, there exists a $\hat{\gamma}_2 > 0$ such that when $\gamma_h = \hat{\gamma}$, $\Delta_a = 0$ and $\Delta_a > 0$ iff $\gamma_h < \hat{\gamma}_2$. When $\gamma_h = 3t_h(b_h - a_h)$, $\Delta_a|_{\gamma_h = 3t_h(b_h - a_h)} = -\frac{\alpha t_h(b_h - a_h)}{2} + \frac{(1-\alpha)\gamma_l}{3}\left(\frac{\gamma_l}{6t_l(b_l - a_l)} + 1\right)$ which is increasing in γ_l. When $\gamma_l = 0$, $\Delta_a|_{\gamma_h = 3t_h(b_h - a_h), \gamma_l = 0} < 0$. When $\gamma_l = 3t_l(b_l - a_l)$, $\Delta_a|_{\gamma_h = 3t_h(b_h - a_h), \gamma_l = 3t_l(b_l - a_l)} = \frac{1}{2}[3(1-\alpha)t_l(b_l - a_l) - \alpha t_h(b_h - a_h)]$, which is positive if and only if $(1-\alpha)t_l(b_l - a_l) > \frac{1}{3}\alpha t_h(b_h - a_h)$. In this case, there exists $\gamma_l < 2t_l(b_l - a_l)$ and $\gamma_h = 2t_h(b_h - a_h)$ such that $\Delta_a > 0$. Given that Δ_a is decreasing in γ_h. Let $\gamma_h' = \gamma_h - \varepsilon$ for a small ε, then there exists $\gamma_l < 2t_l(b_l - a_l)$ and $\gamma_h = \gamma_h' < 2t_h(b_h - a_h)$ such that $\Delta_a > 0$.

Claim 7 *$\hat{\gamma}_2$ is convex and increasing in γ_l.*

By the implicit function theorem, we have

$$\frac{\partial \hat{\gamma}_2}{\partial \gamma_l} = -\frac{\frac{\partial \Delta_a}{\partial \gamma_l}}{\frac{\partial \Delta_a}{\partial \gamma_h}} > 0 \tag{C12}$$

where $\frac{\partial \Delta_a}{\partial \gamma_h} = \frac{\alpha[\gamma_h - 3t_h(b_h - a_h)]}{9t_h(b_h - a_h)} < 0$ as shown above, and $\frac{\partial \Delta_a}{\partial \gamma_l} = \frac{(1-\alpha)[3t_l(b_l - a_l) + \gamma_l]}{9t_l(b_l - a_l)} > 0$.

$$\frac{\partial^2 \hat{\gamma}_2}{\partial \gamma_l^2} = \frac{(1-\alpha)t_h(b_h - a_h)}{\alpha t_l(b_l - a_l)[3t_h(b_h - a_h) - \gamma_h]} > 0 \tag{C13}$$

Hence, $\hat{\gamma}_2$ is a convex function of γ_l.

Claim 8 *$\hat{\gamma}_2 > \hat{\gamma}_1$ iff γ_l is sufficiently large, i.e., $\gamma_l > \hat{\gamma}_l$.*

Consider $\gamma_l = 0$. If $\gamma_h = \varepsilon > 0$ where ε is small, $\Delta_a < 0$ and $\Delta_b < 0$, which implies that $\gamma_h > \hat{\gamma}_2$ and $\gamma_h < \hat{\gamma}_1$. Hence, when $\gamma_l = 0$, $\hat{\gamma}_1 > \hat{\gamma}_2$. By Claim 5, $\hat{\gamma}_1$ is concave and increasing in γ_l. By Claim 7, $\hat{\gamma}_2$ is convex and increasing in γ_l, hence, there exists a $\hat{\gamma}_l > 0$ such that when $\gamma_l = \hat{\gamma}_l$, $\hat{\gamma}_1 = \hat{\gamma}_2$, and $\hat{\gamma}_2 > \hat{\gamma}_1$ iff $\gamma_l > \hat{\gamma}_l$.

Claim 9 *If $(1-\alpha)t_l(b_l-a_l) \in \left(\frac{1}{3}\alpha t_h(b_h-a_h), 3\alpha t_h(b_h-a_h)-2m\right)$, the set defined by $\gamma_h \in (\hat{\gamma}_1, \hat{\gamma}_2)$ is non-empty given that $\gamma_h < 3t_h(b_h-a_h)$ and $\gamma_l < 3t_l(b_l-a_l)$.*

Consider $\gamma_h' = 3t_h(b_h-a_h)-\varepsilon$ and $\gamma_l' = 3t_l(b_l-a_l)-\varepsilon$ for a small $\varepsilon > 0$. It satisfies that $\gamma_h' < 3t_h(b_h-a_h)$ and $\gamma_l' < 3t_l(b_l-a_l)$.

$$\lim_{\varepsilon\to 0} \Delta_a \mid_{\gamma_h=\gamma_h',\gamma_l=\gamma_l'} = \frac{3(1-\alpha)t_l(b_l-a_l)-\alpha t_h(b_h-a_h)}{2} \tag{C14}$$

$$\lim_{\varepsilon\to 0} \Delta_b \mid_{\gamma_h=\gamma_h',\gamma_l=\gamma_l'} = \frac{3\alpha t_h(b_h-a_h)-(1-\alpha)t_l(b_l-a_l)}{2} - m \tag{C15}$$

The above two equations are positive if and only if $(1-\alpha)t_l(b_l-a_l) \in \left(\frac{1}{3}\alpha t_h(b_h-a_h), 3\alpha t_h(b_h-a_h)-2m\right)$. $\lim_{\varepsilon\to 0} \Delta_a \mid_{\gamma_h=\gamma_h',\gamma_l=\gamma_l'} > 0$ implies that $\lim_{\varepsilon\to 0}\gamma_h' < \hat{\gamma}_2$. $\lim_{\varepsilon\to 0} \Delta_b \mid_{\gamma_h=\gamma_h',\gamma_l=\gamma_l'} > 0$ implies that $\lim_{\varepsilon\to 0}\gamma_h' > \hat{\gamma}_1$. Hence, when ε is sufficiently small, there exists at least a point (γ_h', γ_l') that lies in the region defined by $\gamma_h' \in (\hat{\gamma}_1, \hat{\gamma}_2)$ when $\gamma_h' < 3t_h(b_h-a_h)$ and $\gamma_l' < 3t_l(b_l-a_l)$, such that the set where the win-win situation arises is non-empty.

Claim 10 *$\hat{\gamma}_1$ is increasing in m, t_s, $b_s - a_s$, where $s \in \{h,l\}$, and decreasing in α.*

By the implicit function theorem, we have

$$\frac{\partial \hat{\gamma}_1}{\partial m} = -\frac{\frac{\partial \Delta_b}{\partial m}}{\frac{\partial \Delta_b}{\partial \gamma_h}} > 0 \tag{C16}$$

where $\frac{\partial \Delta_b}{\partial m} = -1$ and $\frac{\partial \Delta_b}{\partial \gamma_h} > 0$ as proved above. Similarly, $\frac{\partial \Delta_b}{\partial t_s} < 0$, and $\frac{\partial \Delta_b}{\partial (b_s - a_s)} < 0$. By the implicit function theorem, $\hat{\gamma}_1$ is also increasing in t_s, $b_s - a_s$, where $s \in \{h, l\}$. In addition,

$$\frac{\partial \hat{\gamma}_1}{\partial \alpha} = -\frac{\frac{\partial \Delta_b}{\partial \alpha}}{\frac{\partial \Delta_b}{\partial \gamma_h}} < 0 \tag{C17}$$

as $\frac{\partial \Delta_b}{\partial \alpha} = \frac{\gamma_h^2}{18t_h(b_h - a_h)} + \frac{\gamma_h}{3} + \frac{\gamma_l[6t_l(b_l - a_l) - \gamma_l]}{18t_l(b_l - a_l)} > 0$ given that $\gamma_l < 3t_l(b_l - a_l)$. Hence, $\hat{\gamma}_1$ is decreasing in α.

Claim 11 *$\hat{\gamma}_2$ is invariant with m, decreasing in t_s, $b_s - a_s$, where $s \in \{h, l\}$, and decreasing in α.*

By the implicit function theorem, we have

$$\frac{\partial \hat{\gamma}_2}{\partial m} = -\frac{\frac{\partial \Delta_a}{\partial m}}{\frac{\partial \Delta_a}{\partial \gamma_h}} = 0 \tag{C18}$$

where $\frac{\partial \Delta_a}{\partial m} = 0$. $\frac{\partial \Delta_a}{\partial t_s} < 0$, and $\frac{\partial \Delta_a}{\partial (b_s - a_s)} < 0$. By the implicit function theorem, $\hat{\gamma}_2$ is decreasing in t_s, $b_s - a_s$, where $s \in \{h, l\}$. In addition,

$$\frac{\partial \hat{\gamma}_2}{\partial \alpha} = -\frac{\frac{\partial \Delta_a}{\partial \alpha}}{\frac{\partial \Delta_a}{\partial \gamma_h}} < 0 \tag{C19}$$

as $\frac{\partial \Delta_a}{\partial \alpha} = \frac{\gamma_h[\gamma_h - 6t_h(b_h - a_h)]}{18t_h(b_h - a_h)} - \frac{\gamma_l}{3} - \frac{\gamma_l^2}{18t_l(b_l - a_l)} < 0$ given that $\gamma_h < 3t_h(b_h - a_h)$. Hence, $\hat{\gamma}_2$ is decreasing in α.

Proof of Proposition 2

Δ_a and Δ_b (given in Equations C8 and C9) are the changes in brand A's and brand B's profits by adopting asymmetric design strategy instead of the symmetric unification, and $\Delta_a + m$ and $\Delta_b + m$ are the changes in brand A's and brand B's profits by adopting asymmetric design strategy instead of the symmetric diversification. Δ_a and Δ_b are increasing with an decrease in t_s and $b_s - a_s$ where $s \in \{h, l\}$. Hence, the benefit of adopting asymmetric design strategies is higher when t_s and $b_s - a_s$ are smaller.

Proof of Proposition 3

By Claim 4, brand B has incentives to deviate from symmetric unification (U,U) to asymmetric designs (U,D) if and only if $\gamma_h > \hat{\gamma}_1$. Let $\Delta_{a2} = \Pi_a^*(U,D) - \Pi_a^*(D,D)$ represent brand A's incentive to deviate from symmetric diversification (D,D) to the asymmetric design (U,D). Given that $\Pi_a^*(D,D) = \Pi_a^*(U,U) - m$, it follows that $\Delta_{a2} = \Delta_a + m$. We have the following results:

Claim 12 *There exists a* $\hat{\gamma}_3 > 0$ *such that* $\Delta_{a2} > 0$ *iff* $\gamma_h < \hat{\gamma}_3$.

$\frac{\partial \Delta_{a2}}{\partial \gamma_h} = \frac{\partial \Delta_a}{\partial \gamma_h} < 0$ by proof of claim 6. If $\gamma_h = 0$, then $\Delta_{a2} = \frac{(1-\alpha)\gamma_l^2}{18 t_l (b_l - a_l)} + \frac{(1-\alpha)\gamma_l}{3} + m > 0$. Hence, there exists a $\hat{\gamma}_3 > 0$ such that if $\gamma_h = \hat{\gamma}_3$ then $\Delta_{a2} = 0$. Given that Δ_{a2} is decreasing in γ_h, $\Delta_{a2} > 0$ iff $\gamma_h < \hat{\gamma}_3$.

Claim 13 $\hat{\gamma}_3 > \max(\hat{\gamma}_1, \hat{\gamma}_2)$.

I first show $\hat{\gamma}_3 > \hat{\gamma}_2$. $\Delta_a|_{\gamma_h = \hat{\gamma}_2} = 0$, and $\Delta_{a2}|_{\gamma_h = \hat{\gamma}_2} = \Delta_a|_{\gamma_h = \hat{\gamma}_2} + m = m > 0$. Δ_{a2} is decreasing in γ_h and $\Delta_{a2}|_{\gamma_h = \hat{\gamma}_3} = 0$, hence $\hat{\gamma}_3 > \hat{\gamma}_2$. Now I show $\hat{\gamma}_3 > \hat{\gamma}_1$, which is true if $\gamma_h > \hat{\gamma}_3$ implies that $\gamma_h > \hat{\gamma}_1$. This is equivalent to that if $\Delta_{a2} < 0$ implies that $\Delta_b > 0$. If $\Delta_{a2} < 0$, it implies that $\frac{\alpha\gamma_h - (1-\alpha)\gamma_l}{3} - m > \frac{1}{18}\left[\frac{\alpha\gamma_h^2}{t_h(b_h - a_h)} + \frac{(1-\alpha)\gamma_l^2}{t_l(b_l - a_l)}\right]$, which implies that $\Delta_b > \frac{1}{9}\left[\frac{\alpha\gamma_h^2}{t_h(b_h - a_h)} + \frac{(1-\alpha)\gamma_l^2}{t_l(b_l - a_l)}\right] > 0$. Hence, $\Delta_{a2} < 0$ implies that $\Delta_b > 0$, which proves that $\hat{\gamma}_3 > \hat{\gamma}_1$.

Claim 14 $\hat{\gamma}_3$ *is increasing in* γ_h.

$\frac{\partial \hat{\gamma}_3}{\partial \gamma_h} = \frac{\partial \hat{\gamma}_2}{\partial \gamma_h} > 0$ where the inequality is given by Claim 7.

Claim 15 *When $\gamma_h \in (\hat{\gamma}_1, \hat{\gamma}_3)$, brands choose asymmetric design differentiation.*

When $\gamma_h > \hat{\gamma}_1$, $\Delta_b > 0$ by Claim 4. Hence, brand B has incentives to deviate from (U,U) to (U,D). When $\gamma_h < \hat{\gamma}_3$, $\Delta_{a2} > 0$. Hence, brand A has incentives to deviate from (D,D) to (U,D). It follows that the asymmetric design is an equilibrium. Also by Claim 12, $\hat{\gamma}_3 > \hat{\gamma}_2$ and Claim 9 the set that brands choose asymmetric design contains the set that asymmetric design leads to a win-win situation which is non-empty. Hence, the set where brands choose asymmetric design strategies is non-empty.

Claim 16 *When $\gamma_h \geq \hat{\gamma}_3$, brands choose symmetric diversification.*

When $\gamma_h \geq \hat{\gamma}_3$, $\Delta_{a2} \leq 0$. Hence, brand A has incentives to deviate from (U,D) to (D,D). It follows that if B chooses D, A prefers D. When $\Delta_{a2} \leq 0$, it implies that $\Delta_b > 0$ by proof of Claim 13. Hence brand B has incentives to deviate from (U,U) to (U,D). Therefore, the equilibrium is (D,D).

Claim 17 *When $\gamma_h \leq \hat{\gamma}_1$, brands choose symmetric unification.*

When $\gamma_h \leq \hat{\gamma}_1$, $\Delta_b < 0$ by Claim 4. Hence, brand B has incentives to deviate from from (U,D) to (U,U), i.e., when A chooses U, B prefers U over D. Given that $\hat{\gamma}_1 < \hat{\gamma}_3$ by Claim 13, $\gamma_h \leq \hat{\gamma}_1$ implies that $\gamma_h < \hat{\gamma}_3$. Hence, when $\gamma_h \leq \hat{\gamma}_1$, $\Delta_{a2} > 0$ and brand A has incentives to deviate from (D,D) to (U,D). Therefore, the equilibrium is (U,U).

Proof of Proposition 4

We prove the regions of γ_h and γ_l that lead to symmetric unification (U,U), symmetric diversification (D,D), and asymmetric design (U,D) or (D,U) under simultaneous design decisions are the same as the corresponding regions under sequential decisions. Without loss of generality, let brand A be the first mover and brand B be the follower.

Claim 18 *Brands simultaneously choose (D,D) if and only if they sequentially choose (D,D).*

Define $S^1_{(DD)} = \{(\gamma_h, \gamma_l) \in R^2_+ : (D,D)\}$ and $S^2_{(DD)} = \{(\gamma_h, \gamma_l) \in R^2_+ : (D,D)\}$ as the respective set of γ_h and γ_l in which brands choose (D,D) in simultaneous and sequential moves. I show $S^1_{(DD)} = S^2_{(DD)}$ in two steps. First, I show $S^1_{(DD)} \subseteq S^2_{(DD)}$. Suppose $(\gamma'_h, \gamma'_l) \in S^1_{(DD)}$. Then by Proposition 4, $\gamma'_h \geq \hat{\gamma}_3$ such that $\Pi^*_a(D,D) > \Pi^*_a(U,D)$ in simultaneous moves. This implies that $\Pi^*_b(D,D) > \Pi^*_b(D,U)$, which shows that in sequential moves, if A chooses D, then B prefers D that leads to (D,D) over U that leads to (D,U). By Claim 13, $\hat{\gamma}_3 > \hat{\gamma}_1$. Hence, $\gamma'_h \geq \hat{\gamma}_3$ implies that $\gamma'_h > \hat{\gamma}_1$ which suggests $\Pi^*_b(U,D) > \Pi^*_b(U,U)$. Hence, if A chooses U first, then B prefers D that leads to (U,D) over U that leads to (U,U). Comparing A's payoff in (U,D) and (D,D), A prefers (D,D) as $\Pi^*_a(D,D) > \Pi^*_a(U,D)$. Hence, (D,D) is the equilibrium and $(\gamma'_h, \gamma'_l) \in S^2_{(DD)}$ which implies $S^1_{(DD)} \subseteq S^2_{(DD)}$. Next, I show $S^2_{(DD)} \subseteq S^1_{(DD)}$. Consider $(\gamma'_h, \gamma'_l) \in S^2_{(DD)}$. Then it follows that $\Pi^*_b(D,D) > \Pi^*_b(D,U)$ hence when A chooses D, B chooses D. This implies that $\gamma'_h \geq \hat{\gamma}_3$ and (D,D) is the equilibrium in simultaneous move by Proposition 4. Therefore, $(\gamma'_h, \gamma'_l) \in S^1_{(DD)}$

which implies $S^2_{(DD)} \subseteq S^1_{(DD)}$. Given that $S^1_{(DD)} \subseteq S^2_{(DD)}$, we have proven that $S^1_{(DD)} = S^2_{(DD)}$ and the claim is true.

Claim 19 *Brands simultaneously choose (U,U) if and only if they sequentially choose (U,U).*

Define $S^1_{(UU)} = \{(\gamma_h, \gamma_l) \in R^2_+ : (U,U)\}$ and $S^2_{(UU)} = \{(\gamma_h, \gamma_l) \in R^2_+ : (U,U)\}$ be the set of γ_h and γ_l where brands choose (U,U) in simultaneous and sequential moves respectively. I prove the two sets are equivalent, i.e., $S^1_{(UU)} = S^2_{(UU)}$ in two steps. First, I show $S^1_{(UU)} \subseteq S^2_{(UU)}$. Consider $(\gamma'_h, \gamma'_l) \in S^1_{(UU)}$. By Proposition 4, $\gamma'_h < \hat{\gamma}_1$ and $\Pi^*_b(U,U) > \Pi^*_b(U,D)$. This implies that in sequential moves, if A chooses U, then B prefers U that leads to (U,U) over D that leads to (U,D). If A chooses D, then B can chooses U that leads to (D,U). Given that $\Pi^*_b(U,D) < \Pi^*_b(U,U)$, we know $\Pi^*_a(D,U) < \Pi^*_a(U,U)$, i.e., A is worse off in the asymmetric case than when A chooses U that leads to (U,U). Alternatively, B can choose D that leads to (D,D), in which case A's profit is also lower than in (U,U). Hence, A chooses U and B chooses U, and (U,U) is the equilibrium. Therefore, $(\gamma'_h, \gamma'_l) \in S^2_{(UU)}$ which implies $S^1_{(UU)} \subseteq S^2_{(UU)}$. Next, I show $S^2_{(UU)} \subseteq S^1_{(UU)}$. Suppose $(\gamma'_h, \gamma'_l) \in S^2_{(UU)}$. It implies that when A chooses U, B prefers U over D, i.e., $\Pi^*_b(U,U) > \Pi^*_b(U,D)$. It implies that $\gamma'_h < \hat{\gamma}_1$. By Proposition 4, (U,U) is the equilibrium in the simultaneous move. Hence, $(\gamma'_h, \gamma'_l) \in S^1_{(UU)}$ and $S^2_{(UU)} \subseteq S^1_{(UU)}$. Therefore, $S^1_{(UU)} = S^2_{(UU)}$ and the claim is true.

Claim 20 *Brands simultaneously choose the asymmetric design strategies if and only if they sequentially choose the asymmetric design strategies (U,D) or (D,U).*

Define $S^1_{(UD)} = \{(\gamma_h, \gamma_l) \in R^2_+ : (U,D),(D,U)\}$ and $S^2_{(UD)} = \{(\gamma_h, \gamma_l) \in R^2_+ : (U,D),(D,U)\}$ be the set of γ_h and γ_l where brands choose asymmetric design strategies in simultaneous and sequential moves respectively. I prove the two sets are equivalent, i.e., $S^1_{(UD)} = S^2_{(UD)}$ in two steps. First, I show $S^1_{(UD)} \subseteq S^2_{(UD)}$. Consider $(\gamma'_h, \gamma'_l) \in S^1_{(UD)}$. By Proposition 4, (U,D) is the equilibrium in the simultaneous move when $\gamma'_h \in (\hat{\gamma}_1, \hat{\gamma}_3)$ such that $\Pi^*_b(U,D) > \Pi^*_b(U,U)$ and $\Pi^*_a(U,D) > \Pi^*_a(D,D)$. $\Pi^*_b(U,D) > \Pi^*_b(U,U)$ implies that in sequential move if A chooses U, then B chooses D, hence (U,D) arises. $\Pi^*_a(U,D) > \Pi^*_a(D,D)$ implies that if A chooses D then B chooses U such that (D,U) arises. Therefore, the equilibrium is an asymmetric design choice. Hence, $(\gamma'_h, \gamma'_l) \in S^2_{(UD)}$ which implies $S^1_{(UD)} \subseteq S^2_{(UD)}$. Next, I show $S^2_{(UD)} \subseteq S^1_{(UD)}$. Consider $(\gamma'_h, \gamma'_l) \in S^2_{(UD)}$. Then it follows that either (U,D) or (D,U) is the equilibrium. Suppose (U,D) is the equilibrium. It implies that $\Pi^*_b(U,D) > \Pi^*_b(U,U)$ or $\gamma'_h > \hat{\gamma}_1$ so that when A chooses U, B chooses D. Given that (D,D) is not an equilibrium, it implies that $\Pi^*_b(D,U) > \Pi^*_b(D,D)$, hence $\gamma_h < \hat{\gamma}_3$. By proposition 4, brands simultaneously choose asymmetric designs if $\gamma'_h \in (\hat{\gamma}_1, \hat{\gamma}_3)$. Hence, $(\gamma'_h, \gamma'_l) \in S^1_{(UD)}$ which implies $S^2(UD) \subseteq S^1_{(UD)}$. Therefore, $S^1_{(UD)} = S^2_{(UD)}$ and the claim is true.

In the asymmetric case, we compare brand profits from choosing unification versus profits from choosing diversification and obtain that:

$$\Pi^*_a(U,D) - \Pi^*_a(D,U) = m - \frac{2\left[\alpha\gamma_h - (1-\alpha)\gamma_l\right]}{3} \tag{C20}$$

which is positive and A chooses unification if and only if $m + \frac{2(1-\alpha)\gamma_l}{3} > \frac{2\alpha\gamma_h}{3}$.

Proof of Proposition 5

We solve for the equilibrium functionality locations a_s and b_s, $s \in \{h,l\}$ after solving the pricing stage of the game (see Table 2 for equilibrium prices).

Under symmetric designs, using first order conditions we obtain that:

$$a_h^* = a_l^* = -\frac{1}{4} \tag{C21}$$

$$b_h^* = b_l^* = \frac{5}{4} \tag{C22}$$

Under asymmetric designs, the optimal functionality choices are:

$$a_h^*(U,D) = -\frac{1}{4} - \frac{\gamma_h}{3t_h} \tag{C23}$$

$$a_l^*(U,D) = -\frac{1}{4} + \frac{\gamma_l}{3t_l} \tag{C24}$$

$$b_h^*(U,D) = \frac{5}{4} - \frac{\gamma_h}{3t_h} \tag{C25}$$

$$b_l^*(U,D) = \frac{5}{4} + \frac{\gamma_l}{3t_l} \tag{C26}$$

Comparing the functionality choices under asymmetric design strategies with those under symmetric design strategies, we obtain that the brand A that unifies design produces a low-end product that has more mainstream functionalities and a high-end product that has more niche functionalities, whereas the brand B that diversifies design produces a high-end product that has more mainstream functionalities and a low-end product that has more niche functionalities.

Proof of Proposition 6

Case 1: Symmetric Unification. In this case, switching consumers buy low-end products, as in the main model. Results in the main apply and brand profits are given in Table 2 of the paper.

Case 2: Symmetric Diversification. In this case, switching consumers buy high-end products. This is because these consumers care strongly about social image of consumption. If they were to consume a low-end product, they incur a social loss of $\gamma_l' > \gamma_l$ that is sufficiently strong that they are better off buying a high-end product. In this situation, these consumers switch to buy high-end products and experience an increase of γ_h in the social value of consuming the high-end product that looks different from the brand's low-end product. Essentially, the size of high-end consumers becomes $\alpha + \beta(1-\alpha)$ and the size of the low-end consumers becomes $(1-\beta)(1-\alpha)$ after these consumers switch to buy high-end products. Locations of the marginal consumers are the same as in the main model. Brands' profit functions become:

$$\Pi_a = [\alpha + \beta(1-\alpha)](p_{ah} - c)\theta_h + (1-\beta)(1-\alpha)p_{al}\theta_l - m \quad \text{(C27)}$$

$$\Pi_b = [\alpha + \beta(1-\alpha)](p_{bh} - c)(1-\theta_h) + (1-\beta)(1-\alpha)p_{bl}(1-\theta_l) - m \quad \text{(C28)}$$

First order conditions solve for equilibrium prices: $p^*_{ah} = p^*_{bh} = t_h(b_h - a_h) + c$ and $p^*_{al} = p^*_{bl} = t_l(b_l - a_l)$. Plug these prices into the above profit functions, we can derive the equilibrium profits in this case.

Case 3: Asymmetric Design Strategies. Without loss of generality, suppose brand A unifies design while brand B diversifies design. Switchers buy the low-end product from brand A for its design similarity with A's high-end product. In this case, brands' profit functions are:

$$\Pi_a(S,D) = \alpha(p_{ah}-c)\theta_h + (1-\beta)(1-\alpha)p_{al}\theta_l + \beta(1-\alpha)p_{al} \quad \text{(C29)}$$

$$\Pi_b(S,D) = \alpha(p_{bh}-c)(1-\theta_h) + (1-\beta)(1-\alpha)p_{bl}(1-\theta_l) - m \quad \text{(C30)}$$

First order conditions solve for equilibrium prices: $p^*_{ah} = t_h(b_h - a_h) - \frac{\gamma_h}{3} + c$, $p^*_{bh} = t_h(b_h - a_h) + \frac{\gamma_h}{3} + c$, $p^*_{al} = \frac{4\gamma_l(1+\beta^2)-8\beta\gamma_l-3t_l(1+4\beta)}{12t_l(1-\beta)}$, and $p^*_{bl} = \frac{4\gamma_l(1+\beta^2)-8\beta\gamma_l+3t_l(5-4\beta)}{12t_l(1-\beta)}$. Plug these prices into the above profit functions, we can derive the equilibrium profits in this case. Now we show that the partial derivative of brand profits with respect to β are positive. By assumption, functionalities of products are symmetric, i.e., $b_h = 1-a_h$ and $b_l = 1-a_l$.

$$\frac{\partial \Pi_a(S,D)^*}{\partial \beta} = \frac{(1-\alpha)(2\beta a_l t_l + \beta\gamma_l - \beta t_l - \gamma_l + 6a_l t_l - 3t_l)N}{18(1-\beta)^2 t_l(2a_l-1)} \quad \text{(C31)}$$

where $N = (2\beta a_l t_l + \beta\gamma_l - \beta t_l - \gamma_l - 10a_l t_l + 5t_l)$. We can rewrite $p^*_{al} = \frac{2\beta a_l t_l + \beta\gamma_l - \beta t_l - \gamma_l + 6a_l t_l - 3t_l}{3(\beta-1)} > 0$. It follows that the term in the numerator of (C31) $2\beta a_l t_l + \beta\gamma_l - \beta t_l - \gamma_l + 6a_l t_l - 3t_l < 0$. We can also rewrite $\theta^*_l = \frac{10\beta a_l t_l - \beta\gamma_l - 5\beta t_l - 6a_l t_l + \gamma_l + 3t_l}{6t_l(1-\beta)(1-2a_l)}$. We consider situations there brands compete in the low-end market, i.e., $\theta^*_l \in (0,1)$. The condition $\theta^*_l < 1$ requires that $\frac{2\beta a_l t_l + \beta\gamma_l - \beta t_l - \gamma_l - 6a_l t_l + 3t_l}{6t_l(1-\beta)(1-2a_l)} > 0$, which implies that $2\beta a_l t_l + \beta\gamma_l - \beta t_l - \gamma_l > 3t_l(2a_l - 1)$. The term in the numerator of (C31) $(2\beta a_l t_l + \beta\gamma_l - \beta t_l - \gamma_l + 6a_l t_l - 3t_l) > 2t_l(1-2a_l) > 0$. Hence, the sign of (C31) is positive. Similarly, the partial derivative of brand B's profits with respect to β is also positive. To see this,

$$\frac{\partial \Pi_b(S,D)^*}{\partial \beta} = \frac{(1-\alpha)(2\beta a_l t_l + \beta\gamma_l - \beta t_l - \gamma_l - 6a_l t_l + 3t_l)N}{18(1-\beta)^2 t_l(2a_l-1)} \quad \text{(C32)}$$

where $N = (2\beta a_l t_l + \beta\gamma_l - \beta t_l - \gamma_l + 2a_l t_l - t_l)$. The term in the numerator of (C32) $2\beta a_l t_l +$

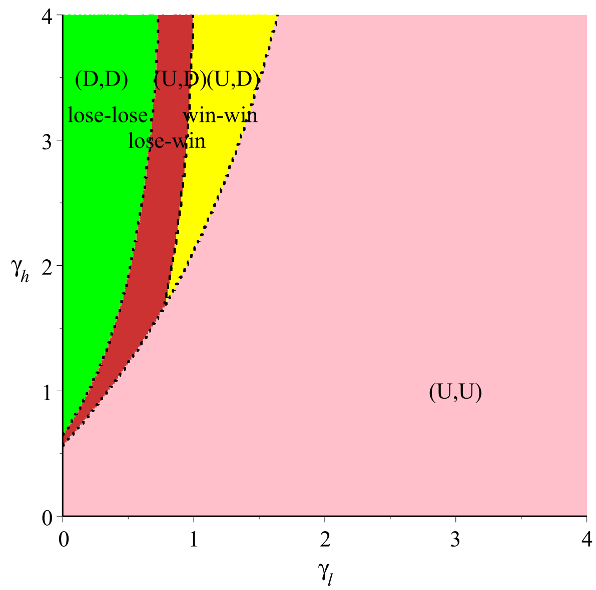
$\beta\gamma_l - \beta t_l - \gamma_l + 2a_l t_l - t_l < 0$ because $2\beta a_l t_l + \beta\gamma_l - \beta t_l - \gamma_l = \beta t_l(2a_l - 1) + \gamma_l(\beta - 1) < 0$ and $2a_l t_l - t_l = t_l(2a_l - 1) < 0$. Therefore, (C31) and (C32) are both positive, i.e., as β increases, brand profits from adopting asymmetric design strategies increase.

Consumer Preferences for Design Differentiation are Endogenous

Locations of the marginal consumer are given in the paper as: $\theta_h = \frac{a_h+b_h}{2} - \frac{p_{ah}-p_{bh}}{2t_h(b_h-a_h)} + \frac{\gamma_h(1-\alpha)(d_a-d_b)}{2t_h(b_h-a_h)}$, $\theta_l = \frac{a_l+b_l}{2} - \frac{p_{al}-p_{bl}}{2t_l(b_l-a_l)} - \frac{\gamma_l\alpha(d_a-d_b)}{2t_l(b_l-a_l)}$. We solve for the brand decisions backward. Brands' profit functions are: $\Pi_a = \alpha(p_{ah}-c)\theta_h + (1-\alpha)p_{al}\theta_l$ and $\Pi_b = \alpha(p_{bh}-c)(1-\theta_h) + (1-\alpha)p_{bl}(1-\theta_l)$. First order conditions give the equilibrium prices: $p^*_{ah}(a_h,b_h,d_a,d_b) = \frac{(b_h-a_h)(2+a_h+b_h)t_h}{3} + \frac{\gamma_h(1-\alpha)\left[d_a\theta_l^e - d_b(1-\theta_l^e)\right]}{3} + c$, $p^*_{bh}(a_h,b_h,d_a,d_b) = \frac{(b_h-a_h)(4-a_h-b_h)t_h}{3} + \frac{\gamma_h(1-\alpha)\left[d_b(1-\theta_l^e) - d_a\theta_l^e\right]}{3} + c$, $p^*_{al}(a_l,b_l,d_a,d_b) = \frac{(b_l-a_l)(2+a_l+b_l)t_l}{3} - \frac{\gamma_l\alpha\left[d_a\theta_h^e - d_b(1-\theta_h^e)\right]}{3}$, and $p^*_{bl}(a_l,b_l,d_a,d_b) = \frac{(b_l-a_l)(4-a_l-b_l)t_l}{3} - \frac{\gamma_l\alpha\left[d_b(1-\theta_h^e) - d_a\theta_h^e\right]}{3}$. The second order conditions are satisfied. Then we solve for brands' functionality decisions. For ease of exposition, we endogenize functionality decisions. First order conditions give that $a^*_h(d_a,d_b) = -\frac{1}{4} + \frac{\gamma_h(1-\alpha)\left[d_a\theta_l^e - d_b(1-\theta_l^e)\right]}{3t_h}$, $a^*_l(d_a,d_b) = -\frac{1}{4} - \frac{\gamma_l\alpha\left[d_a\theta_l^e - d_b(1-\theta_l^e)\right]}{3t_l}$, $b^*_h(d_a,d_b) = \frac{5}{4} - \frac{\gamma_h(1-\alpha)\left[d_b(1-\theta_l^e) - d_a\theta_l^e\right]}{3t_h}$, and $b^*_l(d_a,d_b) = \frac{5}{4} + \frac{\gamma_l\alpha\left[d_b(1-\theta_l^e) - d_a\theta_l^e\right]}{3t_l}$. Equilibrium marginal consumers are at $\theta^*_h(d_a,d_b) = \frac{1}{2} + \frac{2\gamma_h(1-\alpha)\left[\theta_l^e d_a - (1-\theta_l^e)d_b\right]}{9t_h}$ and $\theta^*_l(d_a,d_b) = \frac{1}{2} - \frac{2\gamma_l\alpha\left[\theta_h^e d_a - (1-\theta_h^e)d_b\right]}{9t_l}$. By rational expectations assumption, $\theta_l^e = \theta_l^*(d_a,d_b)$ and $\theta_h^e = \theta_h^*(d_a,d_b)$, we obtain that $\theta^*_h(d_a,d_b) = \frac{1}{2} - \frac{\gamma_h(d_b-d_a)(1-\alpha)[9t_l - 2\alpha\gamma_l(d_a+d_b)]}{4\gamma_h\gamma_l(d_a+d_b)^2\alpha(1-\alpha)+81t_h t_l}$ and $\theta^*_l(d_a,d_b) = \frac{1}{2} + \frac{\gamma_l(d_b-d_a)\alpha[9t_h + 2\gamma_h(d_a+d_b)(1-\alpha)]}{4\gamma_h\gamma_l(d_a+d_b)^2\alpha(1-\alpha)+81t_h t_l}$. We summarize the equilibrium outcome under symmetric and asymmetric design strategies in Table A1 below. There exist a region of γ_h and γ_l where asymmetric design differentiation can arise in equilibrium and be a win-win outcome

Figure C1: Equilibrium Design Strategy with Endogenous Preferences

$(\alpha = \frac{1}{2}, t_h = t_l = 1, a_h = a_l = -\frac{1}{4}, b_h = b_l = \frac{5}{4}, m = \frac{1}{20})$



(see Figure C1).